Hortus Botanicus Cordubensis

NEGLECTED CROPS

1492 from a different perspective

Food and Agriculture Organization of the United Nations

This book contains a study of 65 crops, mostly of American origin, which for social, agronomic or biological reasons have lost their importance over the last 500 years. Some of them have been marginalized with respect to their original function or their potential uses; others have practically been forgotten.

They are plant species which, at other times or under other conditions, played a fundamental role in the agriculture and food supply of indigenous peoples and local communities. Their neglect was in many cases the result of the deliberate suppression of self-sufficient ways of life which characterized traditional cultures.

This work, coordinated by Dr J.E. Hernández Bermejo (Spain) and Dr J. León (Costa Rica), includes the contributions of 31 authors from nine countries. Its preparation was promoted by the Food and Agriculture Organization of the United Nations in collaboration with the Botanical Garden of Córdoba (Spain) as a contribution to the Etnobotánica 92 Programme.

The book comprises an introductory section, which deals with America's plant genetic resources and the processes that caused the marginalization of certain

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Edited by
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Foreword

Throughout history, human beings have used thousands of plant species for food, many of which have also been domesticated. Today only 150 plant species are cultivated, 12 of which provide approximately 75 percent of our food and four of which produce over half of the food we eat. This involution has increased the vulnerability of agriculture and impoverished the human diet. As a result, many local crops that have traditionally been important for feeding the poorest sectors of society are nowadays underutilized or neglected.

There can be no doubt that the use, domestication and cultivation of the most widespread plant species have to a great extent been brought about accidentally and are conditioned by the social, economic and political values of the dominant cultures. It is highly likely that, had the process been carefully planned and the species selected on the basis of the scientific data available to us today, the result would have been different. At present, new biotechnologies constitute a powerful means of halting the involution process and, consequently, of accelerating the domestication of other promising plants as well as the genetic improvement of those that have been neglected. However, the economic and political interest necessary to promote research that would benefit the poorest social strata with the least purchasing power may be lacking.

The discovery of America, which brought into contact two different worlds with their own history, cultures and traditions, at the same time formed a bridge between two ecological macrocosms. When the settlers arrived in America, as well as their language, religion and customs, they brought with them plants that were cultivated on the Eurasian continent. In return, together with tales of amazing riches, mysterious cultures and exotic customs, they took back products of the earth that were unknown in the Old World. Thus began a long-lasting exchange of plants and animals which profoundly transformed eating habits on both sides of the Atlantic in the following centuries.

In the course of this exchange, products that in the past had occupied a prominent place in the economies and food supplies of vast regions, particularly in Latin America, either disappeared or were set aside, giving way to crops from the other continent. Eventually, the change in eating habits that was triggered by the introduction of these plants, which were not always well suited to local agro-ecological conditions, created a food and economic dependence in some countries of Central and South America which, today, remains a serious obstacle to their development.

At a time when the world is experiencing an exponential increase in its population and is anxiously wondering if it will be able to bring an end to the hunger and scarcity of food that now exist in many regions without causing fresh damage to our natural environment, it would seem logical to look to the past for possible solutions in species that have fed humanity throughout its history.

Such is the aim of this book which, beginning with an analysis of the characteristics of these plants, attempts to identify possible areas of research and development in order to facilitate, where possible, their reintroduction in regions to which they had become so well adapted over the centuries. Its purpose, therefore, is eminently practical and, in cooperation with institutions active in this field and with possible donors, it aims at reawakening an interest in the efficient exploitation and distribution of these crops.

This work is also a first step towards implementing the principles stated at the United Nations Conference on the Environment and Development, held recently in Rio de Janeiro, and is in keeping with FAO's continuous effort to find systems and methods of cultivation that make it possible to combine development with a respect for the environment.

Edouard Saouma
Director-General
Food and Agriculture Organization
of the United Nations

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Abbreviations

ARARI
Aegean Regional Agricultural Research Institute (Turkey)

CATIE/GTZ
Tropical Agricultural Research and Training Centre/German Agency for Technical Cooperation

CEPEC
Cocoa Research Centre (Brazil)

CEPLAC
Executive Committee of the Cocoa Farming Plan (Brazil)

CGIAR
Consultative Group on International Agricultural Research

CIAT
International Centre for Tropical Agriculture

CIFAP
Forestry, Agricultural and Livestock Research Centre (Mexico)

CIP
International Potato Centre

CPAA
Agroforestry Research Centre of Western Amazonia (Brazil)

CPATU
Agricultural Research Centre for the Humid Tropics (Brazil)

CSIC
Supreme Council of Scientific Research (Spain)

EEC
European Economic Community

EMBRAPA
Brazilian Agricultural Research Enterprise

ETSIA(M)
Higher Technical School of Agricultural Engineering (Madrid)

IBPGR
International Board for Plant Genetic Resources

IBTA
Bolivian Institute of Agricultural Technology

ICA
Colombian Agricultural Institute

ICARDA
International Centre for Agricultural Research in the Dry Areas

ICRISAT
International Crops Research Institute for the Semi-Arid Tropics

ICTA
Science and Agricultural Technology Institute (Guatemala)

IDIAP
Agricultural Research Institute of Panama

IICA
Inter-American Institute for Cooperation on Agriculture

IITA
International Institute of Tropical Agriculture

INCAP
Institute of Nutrition of Central America and Panama (Guatemala)

INIA
National Institute of Agrarian Research (Portugal)

INIAP
National Institute of Agricultural Research (Ecuador)

INIFAP
National Institute of Forestry and Agricultural Research (Mexico)

INIPA
National Institute of Agricultural Research and Promotion (Peru)

INPA
National Research Institute of Amazonia (Brazil)

INRA
National Institute of Agricultural Research (France)

INTA
National Institute of Agricultural Technology (Argentina)

IUCN
World Conservation Union

JUNAC
Cartagena Agreement Board (Peru)

MAG
Ministry of Agriculture and Livestock (Costa Rica)

MID/INRA
Ministry of Agricultural Development/Nicaraguan Institute of Agrarian Reform (Nicaragua)

NBPGR
National Bureau of Plant Genetic Resources (India)

OAS
Organization of American States

SARH
Secretariat of State for Agriculture and Water Resources (Mexico)

UACH
Autonomous University of Chapingo

UCR
University of Costa Rica

UNAM
National Autonomous University of Mexico

UNSCH
National University of San Cristóbal de Huamanga

USDA
United States Department of Agriculture

VIR
N.I. Vavilov All-Union Scientific Research Institute of Plant Breeding (CIS)

Preface

Conceived as a project by the Food and Agriculture Organization of the United Nations, *Neglected crops: 1492 from a different perspective* was copublished with the Botanical Garden of Córdoba, Spain. This cooperation came about as a result of the "Etnobotánica 92" congress, convened in September 1992 by the Botanical Garden and the City of Córdoba. The contents and aims of the congress were fully consistent with the sentiment behind the planned publication which would thus serve as an initial protocol for discussion at a symposium on neglected crops, oriented towards defining priorities, designing new projects for researching and improving these crops and planning strategies to finance them.

The aim of the book is to analyse the present situation and the prospects for improving certain traditional crops that were more important in other times and have now either been completely forgotten or relegated to a marginal role. After discussing the repercussions that 1492 had on natural resources and ways of life, both in America and Spain, the discovery of America and successive eras are studied, not as historic events that gave rise to a great genetic and cultural flow but, on the contrary, as possible immediate or delayed causes of certain crops being neglected.

The concept of a neglected or "marginalized" species in agricultural terms needs to be made clear. It basically refers to cultivated crops and therefore excludes those species which, in spite of their possible ethnobotanical or economic interest, are taken directly from their wild populations. They are crops which, at other times and under other conditions, were of greater importance in traditional agriculture and in the diets of indigenous peoples and other local communities. It does not necessarily imply promising crops. This is because they have already been cultivated and because the aim of their reinstatement is not to convert them into crops for intensive cultivation or export. Marginalized crops are those whose use and productivity need to be considerably increased as a means of raising the living conditions and improving the diet of ethnic groups and populations accustomed to living in economic systems that have engaged little interchange.

How has this situation of "marginalization" come about? There have been various contributing factors: the introduction of species that supplanted traditional ones; the loss of competitiveness of these species compared with other more productive species; gradual changes in demand; economic, cultural, political or religious prohibitions; and the disappearance of ethnic groups that understood the techniques and uses of the plants as well as their cultivation methods. We need to recognize, as the present study does, that among the social, agronomic and biological reasons for the neglect of such plants, it is the social factors that predominate. In many cases this has been a consequence of the premeditated eradication of self-sufficient ways of life and their replacement by other foreign systems, based on outside interests. Thus, in the traditional societies of Latin America, a dependence on external forces developed and subsequently resulted in poverty.

Four main sections of this book basically deal with Latin America, where three areas of anthropological action are identified, corresponding to the three main centres of phytogenetic diversity and origin of agricultural experiments: Mesoamerica, the Andean region and the Amazon. In keeping with the general approach of "Etnobotánica 92" – organized to analyse the consequences of 500 years of genetic and ethnobotanical exchanges between the two sides of the Atlantic – it seemed logical to include a final section on the marginalization of crops in Spain and its possible connection with 1492.

The list of species studied has been restricted to food crops and, with a few exceptions, to those exclusively of interest as human food. This does not mean that the same phenomenon of marginalization, as defined here, has not occurred in other types of crops. Perhaps the most drastic cases are to be found among industrial crops: dye, fibre or medicinal plants that have now been replaced by synthetic products, whose cultivation is left to the poorest communities which are unable to obtain the artificial substitutes, or which survive to be used at times when, as a result of certain market contingencies, the natural product once again can claim a limited consumption.

Some chapters are monospecific while others refer to groups of crops which are taxonomically and agronomically close. With the aim of meeting the basic objective of improving agricultural species in regions where they are traditionally exploited, attention has been paid to the following points:

Importance of genetic resources. Emphasis is placed both on the direct use of new germplasm with a superior yield, quality or resistance, and its application in previous genetic improvement programmes, using more sophisticated techniques. Mention is also made of conservation programmes and germplasm banks as well as of national and international institutions that coordinate conservation activities and the use of these resources. Genetic variability or biodiversity (known cultivars, related species, wild intraspecific variability, etc.) are evaluated and the current risks of genetic erosion are assessed.

Forms of consumption. The direct causes of or factors contributing to crop marginalization include the loss – either through neglect or cultural suppression – of forms of consumption (preparation, preservation, culinary habits, alternative uses) of foods based on marginalized traditional plants. For this reason, it has been considered of the utmost importance not only to reinstate the use of these crops but also to highlight their nutritional values and forms of preparation.

Prospects for improvement and limitations. The attention of specialists has been centred on rescuing neglected crops and, therefore, on indicating the direction to be taken in order to improve them. Age-old crops must be developed while taking into account the needs of the communities which consume them. With modern technology, it is possible to put improvement programmes into practice but, for this, the starting-point must be the experience acquired by farmers themselves. Research must be carried out at various levels and should range from the study and evaluation of seed material and traditional cultivation practices to the inclusion of a biotechnology suited to farmers' practical problems.

In spite of the fact that the editors of this work laid down a very rigorous theme structure, the diverse nature of the subjects dealt with and the different approaches of specialists from more than nine countries have necessarily led to a certain lack of uniformity which has in fact enriched the work. Highly specific information is frequently provided, much of which has never before been published. Also included are value judgements, observations and personal opinions which may be of use to those who carry out field work.

The first two chapters present an overall view of the biodiversity of American phytogenetic resources and the processes that caused marginalization. This phenomenon is linked directly or indirectly to the introduction of flora from the Old World into America from 1492 onwards.

In the section on Mesoamerica, some little-known beans, gourds and other native cucurbits, custard apples and cherimoyas, prince's feather (huautli) and amaranth, sapodillas, Spanish plums and tomatilloes or husk-tomatoes are studied. The numerous lesser crops of the region have not been included because of their restricted geographical distribution.

In the section on Andean agriculture, crops are grouped into grains and pulses, tubers, roots and fruits. The grains studied include quinoa, canihua (qañiwa), love-lies-bleeding (kiwicha) and Andean lupin (tarwi); tubers include oca, ullucu, bitter potatoes and mashwa; roots include arracacha, leafcup (yacón), maca and mauka; and fruits include the mountain papaw, sweet cucumber and tree tomato.

The section dealing with Amazonian and Caribbean agriculture examines neglected crops in the Amazon region understood in the broad sense and, by extension, species of the Caribbean region and others that are subtropical in environment and origin. There is a study of the cupuaçu, peach-palm, *Paullinia* sp., arazá, feijoa, jaboticaba, Guinea arrowroot, Paraguay tea and yautia or tanier.

The last section examines the possible influence of American flora on the marginalization of various Iberian crops. Leguminous species (for animal feed and human consumption) and horticultural species are considered. Fruit-trees and groups of plants of separate economic interest for human consumption ought to have been included.

Many other crops have not been mentioned and perhaps only a minority of those which urgently need to be rescued have been included but it is hoped that at least a contribution has been made towards increasing awareness of such crops, thereby encouraging an exchange of available information.

What is sought now is the participation of different national and international institutions that may be able to contribute resources, technology and expertise to less developed countries where marginalized crops play an important role as a source of food.

Perhaps what should first be achieved is a change of attitude in Latin American countries themselves regarding the species and the products which are derived from them, but which are currently neglected either because of the passive or disparaging attitude of consumers, or because of the lack of incentives to promote and improve them. These efforts must be accompanied by new studies on postharvest handling, marketing channels and the publicizing of nutritional values, bearing in mind that the prime beneficiaries of this undertaking must be the farmers and consumers.

J.E. Hernández Bermejo
and J. León

Introduction

Plant genetic resources of the New World

The discovery of America brought about the biggest exchange of germplasm in history. Previously, only three species – one cultivated (sweet potato) and two spontaneous (bottle gourd and coconut) – were common to the agricultures of both the Old and the New World. After 1492, the exchange of cultivated species not only radically changed the diet of the majority of humankind but also led to commercial crops being developed in the tropics and a new world economic order being created. The relationship between human beings and cultivated plants affected everything from basic food and clothing requirements to the use of plants for ornamental purposes and leisure.

The first introductions into America – European grains, vegetables and fruits planted in Hispaniola – were unsuccessful but, a few decades later on the highlands of Mexico and the Andes, they produced yields which exceeded those of Europe. On the other hand, bananas, sugar cane and citrus fruits, among others, acclimatized easily to tropical areas. From Africa, yams and other minor crops were introduced. From America and Europe, maize, which arrived shortly after the discovery, had spread throughout the centre of the continent within three or four decades. Later, potatoes, tomatoes, gourds, beans and chilies were slowly incorporated into European cooking, which thereby assumed its present-day characteristics. In Africa, the cassava or manioc and the peanut were introduced, which radically changed the diet in the western part of the continent. Rice, originating in Southeast Asia and taken to America from Spain and Africa, came to constitute a staple food; on the other hand, cottons from the New World displaced African and Asian cottons. In commercial crops, the influence of exchange was decisive: sugar cane was the first agro-industrial product of the New World while coffee from Ethiopia, introduced two centuries ago, became the main product of Latin America, followed by the banana, originating from Southeast Asia. In the opposite direction, cocoa from Brazil has become the main commercial product of West Africa and, together with rubber from the Amazon region, an important export item of Southeast Asia. In Latin America during this century, African grasses have replaced the local species, which are few and of low yield.

The exchange of germplasm is a continuous process in agricultural diversification and genetic improvement. The fact that on both sides of the Atlantic most commercial crops are of foreign origin means that their preservation, evaluation and trade is of world interest. Germplasm losses in Southeast Asia may have more effect on tropical America than on that region itself.

GENETIC RESOURCES

At present, the term "genetic resources" is being employed increasingly instead of germplasm, as it is considered to be broader and more appropriate. Interest in the preservation, documentation

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The author of this chapter is J. León (San José, Costa Rica).

and intensive use of genetic resources is relatively recent. As one of the earth's many natural resources, once it is lost the germplasm of cultivated plants may never be recovered. Its concentration in countries with an incipient agriculture creates particular problems regarding its conservation and trade, although the agricultural systems prevalent in those regions tend to preserve it as seed material.

The range of the genetic resources of cultivated plants varies considerably according to the species. The first category consists of the primitive cultivars, i.e. those resulting from an initial selection made by the farmers. There is no complete list, not even for species of high economic value, by which the number of cultivars could be estimated; in some species there may be dozens, in others hundreds. Most have a restricted geographical distribution and many are grown only for family consumption.

Outside their centre of origin they produce high yields, as certain tests reveal. Their potential value consists of the set of genes resistant to very varied environmental conditions, diseases and pests and, often, their high nutritional value content. They are very prone to genetic erosion, as their populations are small and consequently easy to replace with other cultivars and, since they are used by the poorest social groups, they receive scant attention.

The second category, advanced cultivars, is limited in tropical America to a few species; they are the result of genetic improvement efforts intended to produce high-yielding cultivars that are resistant to diseases and pests or adapted to specific environmental conditions. Some crops originating from the American tropics have undergone genetic improvement in regions with advanced agricultural sectors: North America, Europe and Japan. The cultivars that they gave rise to did not, however, adapt to the prevailing conditions in tropical America.

The third category is made up of the cultivated species' wild populations which subsist in the area where the species has been domesticated. They grow spontaneously and sometimes the action of disruptive selection does not allow an exchange of genes between the wild and cultivated populations. Weeds, which are difficult to define, form a separate group. In primitive agricultural systems, there is no clear line between cultivars, weeds and wild populations because the latter two are also utilized in some cases.

In addition to the species, the cultivated or wild relatives with which an exchange of genes is possible constitute a fourth category which may have an important role in genetic improvement. Frequently, the relations of a cultivated species are used in practices, such as grafting, that require a physiological affinity. In some cases – citrus fruits and ornamental orchids – the genetic resources are extended to other genera in the formation of multigeneric hybrids.

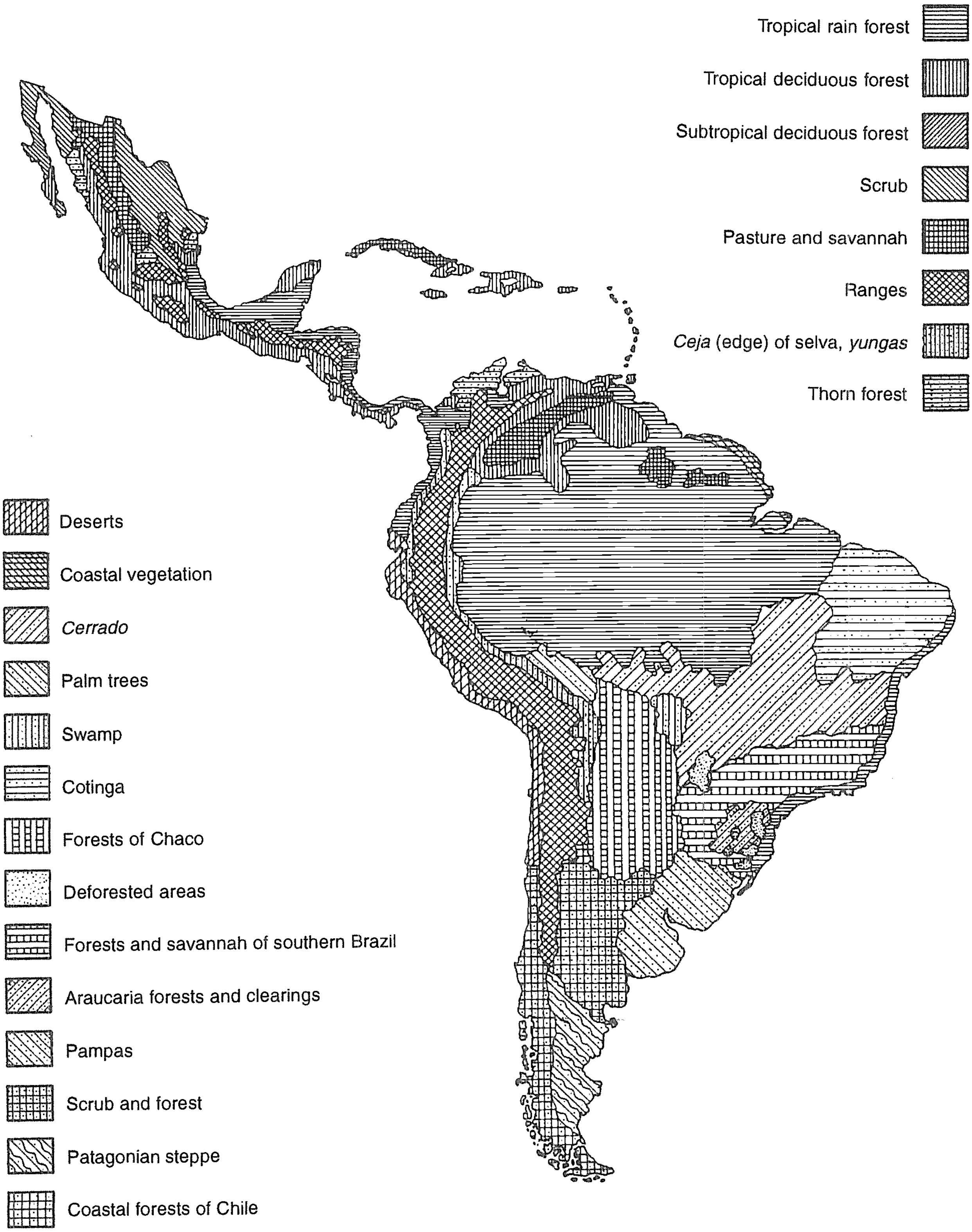
THE MAJOR PHYTOGEOGRAPHICAL REGIONS

The background to the processes determining the richness of the continent's genetic resources may be understood better if we consider their relationship with the distribution of the plant formations and their biodiversity, and with human factors or, in other words, cultural factors. The former is very complex in the tropical region of the New World because of the number of natural landscapes and the differences between them.

Around lat. 25°N, the arid regions of North America, including deserts and semi-deserts, come to and end and areas of greater humidity begin along the coastal areas of Mexico. Running parallel to the coast are the Sierra Madre mountain ranges, traversed by the high and wide central valleys which formed the heart of Mesoamerica. Towards the south, the mountainous areas, ranges and dividing valleys extend as far

FIGURE 1

Major types of vegetation in Mesoamerica, the Caribbean and South America



as Panama, with a break only in Tehuantepec. As far as Nicaragua, the vegetation of the ranges is predominantly of northern origin, and the first high, bleak Andean plateaus appear in Costa Rica. In the low areas there are notable differences between the two slopes. On the Atlantic slope, the rain forest begins south of Tamaulipas and continues over the coastal plains as far as Darien in Panama, broken only in Yucatán by a low, dry forest, and in the north of Nicaragua by extensive pinewoods resulting from specific soil conditions. On the Pacific slope, on the other hand, in areas with alternating seasons, the dry tropical forest extends from Sinaloa to central Panama, with a single break through the humid tropical forest of Osa in Costa Rica. The lowland forests are mainly of southern origin and penetrate Mexico as far as the northern limit of the rain forests or dry forests.

In South America, the tropical rain forest of the Gulf of Darien extends south through the coastal plains as far as Ecuador; it branches north and northeastwards in Colombia and Venezuela, where it borders on a dry tropical forest, similar to that of Mexico in Central America, which changes in coastal areas to semi-desert scrubland, with Cactaceae extending as far as the Caribbean coast.

The Andean ranges present a great diversity of vegetation cover, from the slopes bordering the Pacific, which are desert-like in Peru and Chile, to the vegetation of the bleak plateaus. The eastern slope is generally much more humid and forms a continuous strip from Venezuela to Bolivia (cejas[1] and yungas[2]). The high elevation causes areas of extreme dryness in the Andes, some of which are completely devoid of vegetation, for instance the salt marshes.

In the extreme northeast of the Andes, an area of low humidity, the Orinoco plains, extends from the centre of the continent to the Atlantic, ending in very dry forests on the coast. On the more humid ground to the east of the Orinoco River, there are dry forests and palm groves.

The centre of the continent is covered with the humid tropical forest of the Amazon Orinoco, except for the high savannah of Guyana. This forest, the most extensive in the world, can be divided into several subregions according to the types of vegetation and composition of flora, caused by the expansion of the old plant formations and by environmental conditions. What is important from a phytogeographical point of view is the Obidos breech which crosses the Amazon basin from north to south. It is a separate strip with a lower precipitation of around 1 500 mm, much less than the rest of the Amazon region receives, which divides the region into a western and eastern zone and acts as a barrier to the spread of many species. The upper Amazon, from Obidos to the Andean ranges, is one of the most interesting areas in South America on account of its wealth of flora and genetic resources – numerous crops originated here.

The decrease in humidity south of the Amazon forest gives rise to landscapes of open forest and savannah. The *cerrado* is an enormous area in central Brazil which is relatively low, undulating or with mountain ranges which are not very high and are covered with scattered, low evergreen arboreal vegetation which is denser around water currents. The humidity is favourable to agriculture, which has recently been developed and, if chemical fertilizers are used, soils are productive.

Northeastern Brazil is for the most part covered by the caatinga,[3] with a clear, deciduous forest predominated by palms and cacti. The area

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[1] Jutting edges of upland plains.
[2] Densely wooded valleys.
[3] Stunted, sparse forest which is leafless in the dry season.

offers natural products for collection, such as carnauba wax in the extreme north, but it is a difficult area for agriculture. On the rain forest border in areas with about 1 500 mm of precipitation, there are great formations of babassu, which is an important source of oil. The *cerrado* and the caatinga are poor in native crops, partly because of their abundance of other natural resources and partly because of the adverse conditions for permanent agriculture.

Between the caatinga and the ocean there is a belt of high humidity with rain forest which, in Bahía, is used to a great extent for cacao, cane and other crops. The coastal rain forests are broken to the north of Rio de Janeiro by dry areas, but they continue south almost to lat. 30°.

From the southern limit of the *cerrado* to the Tropic of Capricorn there are several regions with different landscapes, beginning with the palm savannahs in Bolivia in the foothills of the Andes; changing to the dry forest of Chaco which is the largest of these regions; and then to the great marshland of the Mato Grosso; and ending in the mesophytic forests which extend eastwards as far as the coastal rain forests.

BIODIVERSITY OF AMERICAN FLORA

Plant biodiversity in the American tropics comprises two aspects which have not yet been studied in full. The first is the diversity of plant types caused by adaptation to a complex, unstable environment where there is much competition. Species have responded to these conditions by forming characteristics that entail complete changes in the organism (epiphytism, parasitism), or by adapting certain organs, as is the case of lianas or floating plants which adjust to more restricted requirements.

The second aspect, the wealth of families, genera and species, has been studied more, but the inventories made in the New World only cover countries or very small regions, which does not give an idea of the complete situation. It is well known that the richness of flora increases from the lower latitudes towards the equator and that, like the diversity of biological forms, it reaches its highest level in the humid tropics. The number of higher plants in the tropical New World is estimated to be between 60 000 and 70 000. A very high percentage of these include the Compositae, Orchidaceae, Rubiaceae, Cyperaceae, Araceae and Melastomataceae families, which have few components that provide materials for consumption or industry. It is to be hoped, therefore, that there is no correlation between a region's wealth of flora and the number of domesticated plants in it. Thus, in Costa Rica, only one of about 10 000 higher plant species has been domesticated. In Ecuador, whose wealth of flora is unparalleled on the continent, it is surmised that only four species have been domesticated. On the other hand, the areas with the greatest richness of flora are those which offer the best prospects for future use, especially in industry.

CULTURAL RELATIONSHIPS

It is obvious that neither the wealth of flora nor the diversity of the major plant formations are primary factors in domestication. On the contrary, both conditions may be negative: the first because, in a wide range of products, it is easy to find substitutes if one should become scarce; the second because the abundance of a product in a natural formation makes its domestication unnecessary.

Although there is uncertainty as to which species were cultivated in America prior to 1492, their number is estimated to be between 250 and 300. The great majority of them are still at an incipient stage of cultivation and they cannot be categorized as domesticated, if we are to follow the norms laid down by specialists who restrict this concept to those species that have undergone genetic improvement. However, if we accept that the relationship between human beings and cultivated plants has a broader sense, the development and application of cultivation practices and the invention of utilization techniques as factors in the domestication process of a species may be considered to be as important as or more important than genetic improvement.

In tropical America, the paucity of archaeological or historical evidence makes it very difficult to determine the factors which led to domestication and to establish whether this occurred in a limited period or was a long process, whether it occurred in one place or several, and whether it happened just once or recurred in different eras.

Domestication in the New World may have been due to the same causes that were believed to have operated in the Old World: scarcity of harvesting, fishing and hunting resources; population pressure; and environmental changes or cultural transformations. Secondary causes may also be mentioned, such as the convenience of having a resource close at hand rather than having to look for it in the forest, especially if it required only simple handling and propagation methods.

Once the initial stage of domestication had passed, the expansion of crops exposed species to new forces of selection and increased their diversity. Expansion was able to take place by diffusion or migration, as will be described later.

DISTRIBUTION OF GENETIC DIVERSITY

The genetic resources of cultivated plants are not uniformly distributed. A great number of species and varieties are concentrated in tropical and subtropical regions, while they are scarce or completely absent in very extensive areas of temperate zones. Vavilov was the first to report this unevenness in geographical distribution and, although his explanation is still not accepted, his definition of areas with a wealth of genetic resources continues to be valid and useful. There is a close relationship between the eight centres which Vavilov identified as areas of high diversity and the state of agriculture during the discovery. When the Europeans arrived, there were two regions of advanced agriculture in America: Mesoamerica, with centres in Mexico, Guatemala and the Andes, with a similar area in southern Peru. Not only was agriculture more advanced in those two regions, but so were industry, trade, communications and urban development. In these areas, agricultural progress was characterized by a high number of cultivated plants, a small number of domestic animals, the development of irrigation and soil conservation, implements for tillage (for which no draught animals were available) and a food preservation technology which was much more advanced than that which existed in Europe.

Mesoamerica and the Andes had no direct cultural communication. They were separated by an intermediate region, comprising a large part of Central America and northeastern South America, which was far less culturally developed. Several plants were cultivated in both regions, an underlying factor common to the whole continent.

The most widespread cultivated plant which was grown was maize, from the mouth of the Saint Lawrence river in Canada (lat. 52°N) to central Chile (lat. 35°S) and from sea level to 3 900 m altitude. The beans *Phaseolus vulgaris* and *P. lunatus* covered a similar area; the latter was cultivated up to the coasts of Brazil. Tobacco and avocados were also common. It is interesting to note that different species of the genera *Amaranthus, Capsicum, Cucurbita, Gossypium, Physalis* and *Pachyrhizus* were domesticated in Mesoamerica and the Andes.

Botany, archaeology and history have enabled us to confirm that both regions had a significant number of cultivated native species in their central areas, some of which are still found only in those areas. These nuclear areas were surrounded by others which had different environmental conditions and domesticated plants of local origin. From this, a distribution pattern emerges whereby the number of cultivated species and varieties decreases from the nuclear area of a region to its periphery.

To the local component of germplasm in the nuclear and adjacent areas must be added the foreign contribution from introductions made in different eras and from various origins. Before the discovery, cassava, sweet potato, groundnut and annato (arnatto) were already cultivated, possibly originating from other areas of the continent, while calabash or bottle gourd (*Lagenaria siceraria*), probably of African origin, was used from the United States down to Argentina for its fruits, which were used as vessels. In the first stages of agriculture, this process of diffusion began through exchanges, theft, war and conquests among the primitive populations. The success of introductions depended on the adaptability of species to new environments and on their acceptance by consumers. The case of the banana is exemplary; it was introduced at the start of the discovery period and its expansion in tropical America preceded the movement of the conquistadores by ten years. The spread of cultivars resulting from the voluntary or forced migration of human communities may have had less effect, but there is historical evidence to confirm its occurrence. The concentration of genetic resources in Mesoamerica and the Andes, which at the time of the conquest were two very extensive empires, can be explained by the accumulation of germplasm throughout a long history of domesticating local crops and adaptating foreign crops on the basis of a few cultivated species common to both regions.

These two regions of intense concentration of germplasm do, however, occupy a very small area. Beyond the tropics, to the north of Mesoamerica, there were a few isolated cases of domestication: sunflower, Jerusalem artichoke (*Helianthus tuberosus*), *Iva annua*, *Proboscidea parviflora*, *Chenopodium* sp., of which only the first two are known in other regions.

The intermediate zone extends into South America, spanning the basins of the Orinoco, Amazon and Paraguay Paraná. This immense region covers the continent's richest areas in terms of species and environmental diversity. It is here that species of global importance were domesticated: cassava, sweet potato, pineapple, groundnut and many crops in the incipient stages of cultivation. In spite of its enormous size, there are no nuclei with a high concentration of germplasm, and only in the Upper Amazon is there an undefined area of native plants that are still in the incipient stage of cultivation. There is archaeological evidence of extensive ancient human occupation in the intermediate region comparable in age to the occupations of Mesoamerica and the Andes, but no human group attained a culture comparable with that of these civilizations. In order to explain the absence of an advanced agriculture it may be adduced that: in some regions, e.g. the Amazon region, the natural conditions were such that existing plant and animal food resources were sufficient to supply a community with a balanced diet throughout the year; and the low fertility of the soil, the formation of the major rivers and prolonged droughts did not favour the development of a firmly settled civilization.

Finally, in the extreme south of the continent, already outside the tropics, there were isolated cases of domestication. In Chile, the cereals *Bromus mango* and *Elymus* sp. were cultivated until European cereals supplanted them; an oleaginous plant, *Madia sativa*, was cultivated until the eighteenth century. In Argentina and Brazil, cultivation began of *Cucurbita maxima*, a vegetable of international importance.

The Antilles were not an important source of cultivated plants. Only the mammee (*Mammea americana*), which appears to be of West Indian origin, grows wild in the Greater Antilles where it is known by the name "taino". It is doubtful whether arrowroot (*Maranta arundinacea*) was domesticated in the Lesser Antilles as has been suggested; rather, it may have been introduced from South America. The Antilles, especially Hispaniola, were where Europeans first became acquainted with and adopted indigenous names for a good number of American cultivated plants, which then spread throughout the continent.

CHANGES SINCE 1500

Several processes radically affected the state of genetic resources after the discovery and their action varied according to the crop and region while its intensity varied with the era. It is difficult to assess the impact of these processes and to form an accurate idea of the germplasm lost. Historical evidence shows that some species disappeared from cultivation, but it is not possible to evaluate the losses of cultivars.

Two new processes were observed immediately after the discovery. The first was the introduction of livestock, leading to extensive farming which still exists within colonial settings in some regions of Latin America. Extensive livestock farming first occupied the cultivated land that the Indians abandoned either because of the conquest or because of depopulation resulting from disease. To sustain livestock farming on the highlands, Eurasian forage species were introduced while, for the lowlands, African grasses were introduced, some of which turned into obnoxious weeds and practically eliminated the native grasses.

The second process was the introduction of export crops – sugar cane, indigo, coffee, banana, oil-palm – which were established by cutting down primary forests or using agricultural land intended for subsistence crops. The monocultures were transformed by dense sowing and agronomic practices into veritable deserts in terms of their scarce biodiversity.

The processes of urbanization, if this is the name that may be given to the building of dwellings and transport routes, seriously affected the preservation of genetic resources since, in Latin America, the expansion of cities mainly took place around the old population centres which were surrounded by intensely and diversely farmed fields. Urbanization brought about changes in diet which reduced the consumption of traditional foods.

The effects that the change in varieties had on the survival of genetic resources were less important in tropical America. First, because of the lack of genetic improvement or selection programmes in the great majority of crops and, second, because of farmers' resistance to adopting new varieties, especially for food crops. (Farmers usually doubt the properties of improved varieties and consequently prefer traditional varieties, when they are not fully informed of the methods for handling them.)

Another factor that favoured genetic diversity was the sowing of mixtures of cultivars in order to ensure that at least one of them was harvested. The aesthetic aspect of this practice is reflected in the diversity of shapes, colours and sizes of fruit, tubers and other products. In some cases, eating habits and the nutritional and culinary superiority of the primitive cultivars contributed to their survival.

THE CHALLENGE OF CONSERVATION

In what way can a region comprising 30 independent countries and undergoing serious problems in all areas of development maintain the germplasm of approximately 350 cultivated species? Much is being done at the national and regional level, especially for priority crops that are arousing world interest. However, the food production capacity of most crops has not yet been studied.

Preservation of this genetic stock is a complex task which requires the shared responsibility of national institutions and regional and international bodies as well as political decisions guaranteeing the permanent conservation of germplasm. As the great majority of tropical crops have recalcitrant seeds or are propagated vegetatively, they will have to be conserved in live collections. New techniques will have to be developed for the establishment and handling of collections as well as their duplication in different locations.

Many of the crops of the American tropics are exotic and, therefore, more germplasm and an international policy of introduction and exchange will also be required. This genetic wealth should then ensure rich and varied sources of food and industrial products for the most diverse uses in the future.

Preservation of the native germplasm of tropical America will also depend on the establishment of gene banks and protected areas and will be based on the development of markets and technology for the handling and preparation of agricultural products for consumption. To widen the market for such products, it will be necessary to diversify their uses and to launch information campaigns based on traditional knowledge of their nutritional value and organoleptic qualities. With this aim, ethnobotanical research will need to be stepped up and a systematic study of agronomic management and technologies of product preparation undertaken. Recent experience has shown that, with a little time and effort, it is possible to convert certain neglected crops into supermarket goods. Notable failures have also been seen as a result of insufficient planning and experience. However, in some cases traditional approaches to establishing live collections and seed banks have been successfully combined with research on agronomic management and marketing.

Table 1 lists plants originating in the New World. This catalogue would be incomplete if we did not mention ornamental and medicinal plants.

ORNAMENTAL PLANTS

There is historical evidence of the prehistoric cultivation of ornamental genera such as *Dahlia*, *Tagetes* and others in Mexico, but it is in the last two centuries that a great number of American species have been introduced for cultivation, first in Europe then in the United States, many of which have been genetically altered. The families that have provided a great number of species include the Araceae, Bromeliaceae, Cactaceae and Palmae. Other families of commercial importance are the Amaryllidaceae, (*Hymenocallis*, *Hippeastrum*, *Zephyranthes*), the Compositae (*Cosmos*, *Tagetes*, *Zinnia*) and the Solanaceae (*Browallia*, *Brugmansia*, *Nierembergia*, *Petunia*, *Salpiglossis*). Numerous genera in very different families contain species that are extensively cultivated; for instance the genera *Canna*, *Cleome*, *Euphorbia*, *Fuchsia*, *Ipomoea*, *Salvia* and *Verbena*. Of special importance are ornamental plants originating from North America, including genera such as *Calochortus*, *Gaillardia*, *Lewisia*, the cultivation of which began in the colonial era and rapidly expanded to other temperate regions.

MEDICINAL PLANTS

American medicinal plants, particularly those of Mexico, attracted attention immediately after the discovery and it was with these plants that scientific studies of the New World began. For European medicine, which was still at a medieval stage, the discovery of the purgative properties of *Ipomoea jalapa*, the Michoacán root, was evi-

TABLE 1 Cultivated plants originating in the New World, and their probable distribution at the time of the discovery

Family and species	Common names	Distribution
	CEREALS AND OTHER GRAINS	
Amaranthaceae		
Amaranthus caudatus	Love-lies-bleeding, cat-tail, Inca wheat, tumbleweed achís, achita, ataco, coima, kiwicha, sangorache	Ecuador, Argentina
Amaranthus cruentus	Chían, alegría	United States (New Mexico), Guatemala
Amaranthus hypochondriacus	Prince's feather, huautli, alegría	United States (New Mexico), Guatemala
Gramineae		
Zea mays	Maize	Canada, Argentina
Bromus mango[1]	Brome(grass), wild rye	Chile
Elymus sp.[1]	Teca	Chile
Compositae		
Iva annua[1]	–	United States
Chenopodiaceae		
Chenopodium pallidicaule	Canihua, qañiwa, cañahua	Peru, Bolivia
Chenopodium quinoa	Quinoa, quinua, suba	Colombia, Chile
Chenopodium sp.[1] (aff. *buschianum*)	–	United States
Martyniaceae		
Proboscidea parviflora	New Mexico devil's claw	United States
	SPICES AND CONDIMENTS	
Apocynaceae		
Fernaldia pandurata	Loroco	El Salvador
Bombacaceae		
Quararibea funebris	Cacaoxochitl	Mexico
Cyperaceae		
Cyperus sp.	Flatsedge, pripreoca	Amazon region
Compositae		
Eupatorium ayapana	Ayapana	Amazon region
Porophyllum ruderale	Poreleaf, quillquiña	Bolivia
Spilanthes oleracea (*Spilanthes acmella* var. *oleracea*)	Pará cress, berro	Peru
Tagetes graveolens	Huacatay	Peru, Bolivia
Tagetes mandoni	Huacatay, suico	Peru, Bolivia
Myrtaceae		
Pimenta dioica (*Pimenta officinalis*)	Allspice, pimento, Jamaica pepper	Mexico, Guatemala, Antilles
Orchidaceae		
Vanilla planifolia	Vanilla	Mexico
Chenopodiaceae		
Chenopodium ambrosioides	Wormseed, Mexican tea, epazote	Mexico, Peru

[1] Species that have disappeared from cultivation.

TABLE 1 (cont.)

Family and species	Common names	Distribution
	SPICES AND CONDIMENTS (cont.)	
Solanaceae		
Capsicum annuum	Pepper, chili, pimento, bird pepper	United States, northern South America
Capsicum baccatum		South America
Capsicum chinese		Northern South America
Capsicum frutescens		Mesoamerica
Capsicum pubescens		Ecuador, Bolivia
Umbelliferae		
Eryngium foetidum	Mountain coriander, eryngo	Mesoamerica, Antilles
	STIMULANTS	
Agavaceae		
Agave cocui	Cocuy	Venezuela
Agave mapisiga	–	Mexico
Agave salmiana	Pulque, aguamiel	Mesoamerica
Aquifoliaceae		
Ilex paraguariensis	Maté, Brazilian tea, Paraguay tea	Paraguay, Argentina
Erythroxilaceae		
Erythroxylum coca	Coca, ipadú	Northern and central South America
Erythroxylum novo-granatense	Peruvian cocaine	Western South America
Sterculiaceae		
Theobroma angustifolium	Monkey chocolate	Mesoamerica
Theobroma cacao	Cocoa, cacao	Mesoamerica
Sapindaceae		
Paullinia cupana	Guarana	Brazil
Paullinia yoco	Yoco	Colombia, Ecuador
	FIBRES	
Agavaceae		
Agave angustifolia var. *letonae*	Salvador henquen, maguey, letona agave	El Salvador
Agave cantala	Cantala, Manila maguey, Bombay aloe	Mexico
Agave fourcroydes	Henequen, henequen agave	Mexico
Agave sisalana	Sisal, Bahama hemp, true sisal, sisal agave, green agave	Mexico
Furcraea andina	Furcrea, chuchao, cabuya	Ecuador, Peru
Furcraea cabuya	Cabuya, pita, furcrea	Costa Rica, Colombia
Furcraea foetida (Furcraea gigantea)	Piteira furcrea, giant lily, Mauritius hemp	Colombia, Venezuela
Furcraea humboldtiana	Cocuiza, Humboldt furcrea	Colombia, Venezuela
Furcraea macrophylla	Fique, fique furcrea	Colombia
Bromeliaceae		
Aechmea magdalenae	Pita floja	Mexico, Venezuela, Ecuador
Ananas erectifolius	Carúa	Brazil
Neoglaziovia variegata	Caroa, carúa	Brazil
Cyclanthaceae		
Carludovica palmata	Toquilla, Panama hat palm	Guatemala, Peru, Brazil

TABLE 1 (cont.)

Family and species	Common names	Distribution
	FIBRES (cont.)	
Malvaceae		
Gossypium barbadense	Sea island cotton, West Indian cotton	Northern South America, Guatemala, Belize, Antilles
Gossypium hirsutum	Upland cotton, hairy cotton	Mesoamerica, Antilles
Palmae		
Attalea funifera	Bahia piassava, piassalba, coquilla, piasava, piasaba	Brazil
	FRUITS AND NUTS	
Anacardiaceae		
Anacardium occidentale	Cashew nut, acajou	Venezuela, Brazil
Spondias mombin (Spondias lutea)	Yellow mombin, taperebá, jobo	Mexico, Brazil, Antilles
Spondias purpurea (Spondias mombin)	Spanish plum, red mombin, ciruelo, jocote	Mesoamerica
Spondias tuberosa	Imbú	Northeastern Brazil
Annonaceae		
Annona cherimola	Cherimoya, cherimoyer, chirimoyer, custard apple	Ecuador, Peru, Mexico (?)
Annona diversifolia	Ilama, papausa	Mexico, El Salvador
Annona muricata	Soursop, guanabana, graviola	Panama, Brazil, Antilles
Annona purpurea	Soncoya	Mexico, Panama
Annona reticulata	Bullock's heart, sugar apple, custard apple	Mesoamerica, Antilles
Annona scleroderma	Poshte, quave	Guatemala
Annona squamosa	Sweetsop, sugar apple, custard apple, anona	Mexico, Antilles
Rollinia jimenezi	Anonillo	Mexico, Costa Rica
Rollinia mucosa	Biriba	Brazil
Rollinia rensoniana	Churumuyo	El Salvador
Apocynaceae		
Couma utilis	Sowa, sorva	Brazil, Amazon region
Macoubea witotorum	–	Colombia, Amazon region
Araceae		
Monstera deliciosa	Ceriman, cheeseplant	Mexico, Panama
Bignoniaceae		
Parmentiera aculata	Yellowtaper candletree, cuajilote	Mesoamerica
Bombacaceae		
Patinoa almirajo	Almirajo	Colombia
Quararibea cordata	Sapote, zapote, sapodilla	Colombia, Brazil, Peru
Bromeliaceae		
Ananas comosus	Pineapple, ananas, nana	Mexico, Brazil
Cactaceae		
Acanthocereus pentagonus	Barbwire acanthocereus, pitaya	Mexico, Antilles
Hylocereus ocamponis	Pitaya	Mexico (?)
Hylocereus undatus	Night-blooming cereus	Mexico
Opuntia amyclaea	Prickly pear, tuna blanca	Mexico

TABLE 1 (cont.)

Family and species	Common names	Distribution
	FRUITS AND NUTS (cont.)	
Cactaceae (cont.)		
Opuntia ficus-indica	Indian fig, Barbary fig, prickly pear, tuna castilla	Mexico (?)
Opuntia megacantha	Tuna, mission prickly pear	Mexico
Opuntia robusta	Tuna camuesa	Mexico
Opuntia streptocantha	Tuna cardona	Mexico
Opuntia undulata	–	Mexico
Pereskia aculeata	Barbados gooseberry, guamacho	Northern South America, Antilles
Caricaceae		
Carica × heilborni (Carica pentagona, Carica chrysopetala)	Babaco, higacho	Ecuador
Carica papaya	Papaw, papaya	Southern Central America
Carica pubescens	Mountain papaw, papayuela	Northern South America, Colombia, Venezuela, Ecuador
Caryocaraceae		
Caryocar villosum	Piquiá, piquia-ete	Amazon region
Chrysobalanaceae		
Chrysobalanus icaco	Icaco, icaco cocoaplum	Tropical America
Couepia bracteata	Pajora	Amazon region
Couepia longipendula	Castanha de galina	Amazon region
Couepia polyandra	Olosapo	Mesoamerica
Couepia subcordata	Umarirana	Amazon region
Licania platypus	Zunzapote, sansapote	Mesoamerica
Cucurbitaceae		
Melothria dulcis	Ococa	Costa Rica, Panama
Sterculiaceae		
Theobroma bicolor	Tiger cocoa, Nicaragua cocoa	Amazon region
Theobroma grandiflorum	Cupuaçu, cupuassu	Brazil
Ebenaceae		
Diospyros digyna (Diospyros ebenaster)	Black sapote, Indian ebony persimmon	Mexico
Guttiferae		
Mammea americana	Mammee apple, toddy-tree	Antilles
Platonia insignis	Bacury, bakury bakuri guiana orange	Brazil, Paraguay
Rheedia madruno	Madrone rheedia, arbutus	Colombia, Ecuador
Rheedia macrophylla	Longleaf rheedia, bacuripari, bakupari	Amazon region
Icacinaceae		
Poraqueiba paraensis	Umari	Amazon region
Lauraceae		
Bielschmieidia anay	Anay	Mexico, Guatemala
Persea americana	Avocado pear, aguacate, alligator pear, palta	Mexico, Peru
Persea schiedeana	Coyo avocado	Mexico, Costa Rica
Lecythidaceae		
Bertholletia excelsa	Brazil nut, Pará nut	Amazon region
Gustavia superba	Paco, membrillo	Panama, Colombia
Grias neuberthi	Sacchamango	Amazon region
Lecythis usitata	Sapucaia nut	Amazon region

TABLE 1 (cont.)

Family and species	Common names	Distribution
FRUITS AND NUTS (cont.)		
Leguminosae, Mimosoideae		
Inga cinnamomea	Inga, ingá-assú	Amazon region
Inga densiflora	Guamo, guabo	Costa Rica, Venezuela
Inga edulis	Food inga, ingá-cipó	Amazon region
Inga fagifolia	Ingá-chichi	Mexico, Brazil, Antilles
Inga feuillei	Pacae, pacay	Peru
Inga jinicuil	Jinicuil	Mexico
Inga macrophylla	Ingá-péua	Amazon region
Inga paterno	Paterno	El Salvador
Inga ruiziana	Gumo	Nicaragua, Peru, Brazil
Inga setifera	Ingá dos índios	Amazon region
Leguminosae, Cesalpinioideae		
Cassia leiandra	Marimari	Amazon region
Leguminosae, Papilionoideae		
Arachis hypogaea	Peanut	Mexico, Argentina, Antilles
Malpighiaceae		
Bunchosia armeniaca	Green plum, ciruela de fraile	Amazon region
Byrsonima crassifolia	Nance, golden spoon	Mexico, Brazil
Malpighia glabra	Barbados cherry, acerola, azarole	Antilles
Myrtaceae		
Campomanesia guazumifolia (Britoa sellowiana)	Guabiroba	Brazil
Eugenia brasiliensis	Grumichama, Brazilian cherry	Brazil
Eugenia floribunda	Rumberry eugenia	Antilles
Eugenia cabelluda	Cabelluda	Brazil
Eugenia klotz	Peradocampo	Brazil
Eugenia luschnathiana	Pitomba	Brazil
Eugenia pyriformis	Uvalha	Brazil
Eugenia stipitata	Arazá	Amazon region
Eugenia uniflora	Surinam cherry, pitanga	Brazil
Feijoa sellowiana	Feijoa, pineapple guava	Brazil
Myrciaria cauliflora	Jaboticaba	Brazil
Myrciaria dubia	Camucamu	Amazon region
Myrtus ugni	Ugni (molinae), Chile guava	Chile
Paivaea lansdorfi	Cambuci	Brazil
Psidium acutangulum	Arazá, pera	Brazil
Psidium cattleianum	Pineapple guava, purple guava	Brazil
Psidium friedrichsthalianum	Costa Rican guava, cas	Mexico, Panama
Psidium guajava	Common guava, apple-shaped guava	Mexico, Brazil
Psidium sartorianum	Arrayán	Mexico, El Salvador
Moraceae		
Brosimum alicastrum	Breadnut, ramon, ojoche	Mexico, Brazil
Pourouma cecropiaefolia	Uvilla, mapati	Amazon region
Palmae		
Bactris gasipaes	Peach-palm, pejibaye, pupunha, pejivalle chontaduro	Honduras, Brazil
Passifloraceae		
Passiflora edulis	Purple granadilla, passionfruit, maracuyá	Brazil
Passiflora ligularis	Sweet granadilla	Mexico, Peru
Passiflora maliformis	Granadilla	Antilles, northern South America
Passiflora mollissima	Banana passionfruit tacso, curuba, curuba passionfruit	Colombia, Peru

TABLE 1 (cont.)

Family and species	Common names	Distribution
	FRUITS AND NUTS (cont.)	
Passifloraceae (cont.)		
Passiflora popenovii	Granadilla de Quijos, softleaf passionfruit	Ecuador
Passiflora quadrangularis	Giant granadilla, badea	Northern South America
Passiflora tripartita	Tacso	Ecuador
Rhamnaceae		
Ziziphus joazeiro	Jujube	Brazil
Rosaceae		
Crataegus pubescens	Mexican hawthorn, manzanita, tejocote	Mexico
Fragaria chiloensis	Pine strawberry, pineapple strawberry	Peru, Chile
Prunus serotina ssp. *capuli*	Capulin	Mexico, Guatemala
Rubus glaucus	Mora	Guatemala, Ecuador
Rubiaceae		
Borojoa patinoi	Borojó	Colombia
Borojoa sorbilis	Puruí grande	Brazil
Genipa americana	Genip	Mexico, Brazil, Antilles
Rutaceae		
Casimiroa edulis	White sapote, Mexican apple, casimiro apple, matasano	Mexico, Costa Rica
Sapindaceae		
Melicoccus bijugatus	Mamoncillo, mamón	Antilles, Colombia, Venezuela
Talisia esculenta	Pitomba	Brazil, Paraguay, Bolivia
Talisia floresii	Coloc	Mexico, Guatemala
Talisia olivaeformis	Cotoperis	Mexico, Guatemala, Colombia, Venezuela
apotaceae		
hrysophyllum cainito	Star apple, caimito	Antilles, Northern South America
lanilkara zapota	Sapodilla (plum), chiku, chicle, chicozapote, naseberry, beef apple	Mexico, Costa Rica
outeria arguacoensium	Manzano	Colombia
outeria caimito	Abiu, caimo	Amazon region
uteria campechiana	Canistel	Mexico, Panama
uteria hypoglauca	Pan de vida	Mexico, El Salvador
uteria macrocarpa	Cutiti grande	Amazon region
uteria macrophylla	Cutité, riba	Amazon region
uteria obovata	Lúcumo	Ecuador, Chile
uteria pairiry	Pariri	Amazon region
uteria sapota	Sapote, marmalade plum, mammee zapote	Mexico, Panama
uteria ucuqui	Ucuquí	Amazon region
lanaceae		
phomandra betacea	Tree tomato, tamarillo	Andes, Colombia, Bolivia
ysalis peruviana	Cape gooseberry	Colombia, Bolivia
lanum muricatum	Pepino, sweet cucumber, pear melon	Colombia, Bolivia
lanum quitoense	Naranjilla, lulo	Colombia, Ecuador
lanum sessiliflorum	Topiro, cocona	Amazon region
glandaceae		
glans boliviana	Bolivian black walnut	Peru, Bolivia
glans honorei	Ecuador walnut	Ecuador
glans neotropica	–	Ecuador, Peru

TABLE 1 (cont.)

Family and species	Common names	Distribution
	VEGETABLES	
Agavaceae		
Yucca elephantipes	Izote, bulbstem yucca	Mexico, Guatemala
Asclepiadaceae		
Vincetoxycum salvini	Cuchamper	Guatemala, Costa Rica
Araceae		
Xanthosoma brasiliensis	Belembe	Brazil
Cactaceae		
Opuntia spp.	Prickly pear	Mexico
Caricaceae		
Carica monoica	Col de montaña	Peru
Cucurbitaceae		
Cucurbita argyrosperma	Cushaw, calabaza, saquil, pipián, pipitoria	Mexico, Guatemala
Cucurbita ficifolia	Cidra, sidra, fig leaf squash, chilacayote, Malabar gourd	Mexico, Guatemala
Cucurbita maxima	Winter squash	Argentina
Cucurbita moschata	Pumpkin, winter squash, musky squash, cushaw China squash	Mexico, Guatemala
Cucurbita pepo	Pumpkin, vegetable marrow, summer pumpkin, autumn pumpkin	Mexico, Guatemala
Cyclanthera explodens	Artillery cyclanthera, pepino diablito	El Salvador, Peru
Cyclanthera pedata	Prickle cyclanthera, caígua	Andes
Sechium edule	Chayote, cho-cho, chow chow, christophine, Madeira marrow, vegetable pear	Mexico, Guatemala
Sechium tacaco	Tacaco	Costa Rica
Sicana odorifera	Casabanana	Northern South America (?)
Euphorbiaceae		
Cnidoscolus chayamansa	Chaya, spurge	Mexico, Guatemala
Manihot esculenta	Cassava, manioc, mandioca, tapioca, gari	Amazon region
Leguminosae, Papilionoideae		
Crotalaria longirostrata	Tachipilin	Mexico, El Salvador
Marantaceae		
Calathea macrosepala	Chufle	Guatemala, El Salvador
Palmae		
Bactris gasipaes	Peach-palm, pejibay(e), pejivalle	Honduras, Brazil
Chamaedorea tepejilote	Pacaya	Mexico, Guatemala
Euterpe oleracea	Assai, assai palm, assai enterpe, cabbage enterpe	Brazil
Portulacaceae		
Talinum triangulare	Potherb fameflower	Northeastern South America
Chenopodiaceae		
Chenopodium berlandieri spp. *nuttalliae*	Pitseed goosefoot	Mexico
Solanaceae		
Lycopersicon esculentum	Tomato	Mexico

TABLE 1 (cont.)

Family and species	Common names	Distribution
VEGETABLES (cont.)		
Solanaceae		
Physalis philadelphica	Tomatillo, ground cherry, husk-tomato, jamberry	Mexico, Guatemala
Solanum americanum	Hierba mora, nightshade	Guatemala, El Salvador
Solanum sp.	Nightshade	Guatemala
Vitaceae		
Cissus gongyloides	Marble treebine	Amazon region
GRAIN LEGUMES		
Leguminosae, Papilionoideae		
Canavalia ensiformis	Jack bean, sword bean, sabre bean, Jamaican horse bean	Peru
Erythrina edulis	Basul	Colombia, Peru
Lupinus mutabilis	Andean lupin, South American lupin	Colombia, Bolivia
Phaseolus acutifolius	Tepary bean	United States, Costa Rica
Phaseolus coccineus	Scarlet runner bean, ayacote, patol, botil	Mexico, Guatemala
Phaseolus lunatus	Butter bean, Burma bean, duffin bean, Rangoon bean, Lima bean	United States, Chile
Phaseolus polyanthus	Botil	Mexico
Phaseolus vulgaris	Kidney bean, French bean, flageolet bean, dwarf bean, navy bean, string bean, haricot bean, baked bean, field bean	United States, Argentina
OIL CROPS		
Compositae		
Helianthus annuus	Common sunflower	United States, Mexico
Madia sativa[1]	Madia oil plant, tarweed, melosa	Chile
Chrysobalanaceae		
Licania sclerophylla	Oiticica	Brazil
Euphorbiaceae		
Caryodendron orinocensis	Tacay nut, inchi	Amazon region, Orinoco
Labiatae		
Salvia hispanica	Mexican chia	Mexico, Guatemala
Leguminosae, Papilionoideae		
Dipteryx odorata	Tonka bean	Northeastern South America
Myrtaceae		
Pimenta racemosa	Bay rum tree	Antilles
ROOTS AND TUBERS		
Araceae		
Xanthosoma sagittifolium	Tannia, tania, tanier, new cocoyam, yautia	Mexico, Brazil, Antilles

[1] Species that have disappeared from cultivation.

TABLE 1 (cont.)

Family and species	Common names	Distribution
	ROOTS AND TUBERS (cont.)	
Basellaceae		
Ullucus tuberosus	Ullucu, Oca quina	Venezuela (Andes), Argentina
Cannaceae		
Canna edulis	Achira, Queensland arrowroot, tous-les-mois	Western Andes
Compositae		
Helianthus tuberosus	Jerusalem artichoke	United States
Polymnia sonchifolia	Leafcup yacón	Venezuela (Andes), Argentina
Convolvulaceae		
Ipomoea batatas	Sweet potato, yam, kumara, Brazilian arrowroot	Mexico, Brazil, Antilles
Cruciferae		
Lepidium meyenii	Maca, pepper grass, pepper weed	Peru (Andes)
Dioscoreaceae		
Dioscorea trifida	Cush-cush, yampi yam	Northern South America
Euphorbiaceae		
Manihot esculenta	Cassava, manioc, mandioca, tapioca, gari	Mexico, Brazil, Antilles
Iridaceae		
Tigridia pavonia	Tiger flower	Mexico
Leguminosae, Papilionoideae		
Pachyrhizus ahipa	Ahipa, yam bean	Peru, Argentina
Pachyrhizus erosus	Yam bean, manioc bean, jícama	Mesoamerica
Pachyrhizus tuberosus	West Indies yam, jícama	Colombia (western Andes), Peru
Marantaceae		
Calathea allouia	Guinea arrowroot, topinambour, topi-tampo, topi-tamboo	Northern South America, Antilles
Nyctaginaceae		
Mirabilis expansa	Mauka, chago	Ecuador, Bolivia
Oxalidaceae		
Oxalis tuberosa	Oca	Colombia (Andes), Chile
Solanaceae		
Solanum tuberosum	Potato	Venezuela, Chile
Tropaeolaceae		
Tropaeolum tuberosum	Añu, mashwa	Colombia (Andes), Bolivia
Umbelliferae		
Arracacia xanthorrhiza	Arracacha, apìo, Peruvian parsnip, white carrot	Colombia, Bolivia
	DYESTUFFS	
Bixaceae		
Bixa orellana	Annato, arnatto, roucou, achiote, bixa	Mexico, Brazil, Antilles
Cucurbitaceae		
Lagenaria siceraria	Calabash, bottle gourd	United States, Argentina, Antilles

TABLE 1 (cont.)

Family and species	Common names	Distribution
	MISCELLANEOUS	
Bambusa angustifolia	Bamboo, guadua	Colombia
Stevia rebaudiana	Caa-ehe, cahahé	Paraguay
Nicotiana rustica	Aztec tobacco, wild tobacco	Canada, South America
Nicotiana tabacum	Tobacco	Mexico, South America

dently sufficient reason to justify Dr Francisco Hernández' (1517-1587) expedition to New Spain. Numerous plants were included in the European pharmacopoeia and some of them, despite their synthetic substitutes, are still of worldwide importance; for example, the genera *Cinchona, Dioscorea, Ipecacuanha* and *Smilax*. The first three of these have been cultivated but a large proportion of their supply for consumption is gathered. Most medicinal substances are obtained from the wild plants and, in many cases, it is not certain if they have the properties attributed to them. Bordering on the medicinal area are the hallucinogenic plants, distributed among numerous higher plant families; for instance, the Cactaceae (*Lophophora, Trichocerus*), the Leguminosae (*Adenanthera, Erythrina*), the Myristicaceae (*Virola*) or fungi (*Psylocibe*).

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Introduction of flora from the Old World and causes of crop marginalization

The effects of the diffusion of American crops such as the potato, maize, sunflower and tomato in Europe, and of the extensive use of agricultural products derived from other American plants such as cotton, cocoa and cochineal berry are fairly well documented. What are not so well known are the repercussions of the introduction into America of crops and products from other parts of the world. In this chapter, an attempt will be made to analyse the marginalization of native plants in Latin America, especially in face of introduced European agricultural crops, products and methods and ideas as well as their subsequent local development.

Several problems arise when studying the neglect of native crops that resulted from the conquest of the greater part of America. These include:

- difficulties of a conceptual nature concerning terms such as cultivated plant and marginalization;
- the destruction of pre-Hispanic vestiges which may have shown the stage reached in agriculture when the Europeans arrived on the new continent (the accounts given by the conquistadores, the main ones to have been handed down to posterity, are lacking in objectivity);
- the variety of events and contradictory processes which have occurred on the Latin American subcontinent over the last 500 years and the difficulty of conducting a general analysis of the phenomenon;
- the size of Latin America and its natural, cultural and historical diversity, which requires a regionalized approach to understanding the marginalization of plants.

From an economic point of view, the fact that various previously neglected plants are being used more intensively holds great promise now that both modern society and traditional communities are requiring additional products to meet their numerous needs. The study of traditional agriculture is providing very valuable information that serves to reinforce the modern trend of seeking sustainable agricultural development. This research also benefits biology and agronomy by contributing knowledge on the evolutionary process under domestication, the adaptation of crops, production techniques and agricultural development.

There is much illustrative information on the large number of plants that were being used in some American areas when the Europeans arrived and on those that are being used nowadays in traditional rural communities. In the "Códice florentino", 724 plants are mentioned of which only 382 have been identified botanically. At the moment, one Totanac community is using 325 species of a total of 482. The Seris, Tarahumaras and Huastecos are using 75, 137 and 201 species, respectively, for food. This indicates that the traditional communities, including the

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indigenous American communities at the time of the Europeans' arrival, used several hundred plants from their environment, while the populations with a heavy Western influence used much fewer.

A distinction should be made between: wild plants, which appear spontaneously in natural ecosystems; plants that appear spontaneously on tilled ground and generally in areas disturbed by human beings; cultivated plants, which are the product of human toil and dedication; and domesticated plants, which have undergone profound genetic transformations as a result of domestication and which are generally unable to survive unless cared for by humans. The plants used by American societies fit into all of the categories mentioned.

If this classification is accepted, it would be appropriate to include among wild plants almost all the plant diversity existing when the Europeans arrived, while cultivated plants would comprise at least the majority of those indicated by Vavilov (1931) and other authors as crops originating from America – between 49 and 104 species for Mesoamerica and 45 for the Andean region. The number of species actually domesticated by the indigenous peoples before the arrival of Christopher Columbus was lower, as many of the species mentioned earlier were only in the process of domestication while some should be considered wild and a high number spontaneous on tilled ground.

It is known that traditional societies frequently use and conserve a variety of cultivars of one single species. For this reason, the phenomenon of marginalization should not be reduced to the displacement of botanical species but should also include the neglect of cultivars and traditional varieties within the same species through replacement by others or by a small number of variants or forms of that same species. This is usually referred to as genetic erosion. If this point of view is accepted, it would follow that, on account of the European conquest, the extent of the marginalization of American plants has perhaps been somewhat wider than could be evaluated at the species level only.

The basis for an assessment of the marginalization of useful plants should be a comparison of the area's inventory of its flora as well as of the useful plants indicated in the codices and early studies carried out by Europeans in America, on the one hand, with those plants currently used in traditional communities and in commercial agricultural production, on the other. The close relationship existing between the diversity of flora, useful plants and native crops must always be kept in mind.

In traditional societies, especially, plants are not cultivated individually but in complex agronomic ecosystems. Although one or more plants are the central agricultural objective (maize, beans, gourd, potato, peach-palm or pejibaye), many others are also used: therefore, in order to evaluate the displacement of useful plants brought about by the conquest, it would also be necessary to consider the damage suffered by pre-Hispanic agricultural systems and the marginalization of many plants that were used in earlier times as a result of the destruction of hydraulic infrastructure, the annihilation of local populations, the development of livestock rearing, etc.

DEGREE OF MARGINALIZATION OF AMERICAN PLANTS

From the literature on the exploration, conquest and colonization of America by the Iberian countries, it is not clear whether the introduced crops that displaced the existing ones were imposed immediately and extensively. Moreover, in the sixteenth and seventeenth centuries there does not seem to have been a profound transformation of American agriculture. Indeed, according to recent studies, no proof has been found to suggest that the production of plants such as amaranth, clearly intended for religious and idolatrous uses and therefore contrary to the ideas that were being imposed, stopped as a result of specific prohibitions.

The introduction of plants from the old continent began in 1493 with the second voyage of Christopher Columbus. For many, the Antilles served as a centre of adaptation and dispersion. Hernán Cortés, in the *Cuarta carta de relación a Carlos V*, requested that every ship "should carry a quantity of plants and should not set sail without them because it will be a great thing for the population and its perpetuation". The introduction of plants and animals established the basis for colonization.

With a few exceptions (banana, sugar cane, mango and others), the Spanish brought Mediterranean crops which could only adapt to the high temperate zones of America. These were densely populated areas which were supplied with Spanish products cultivated in adjoining regions.

Monasteries served as acclimatization centres for European plants which, in some cases, expanded further and were grown in the new producer areas. One advantage of the introduced crops was that they could be used in cold areas where mild frosts were recorded in the winter periods. Many crops of the Old World were maintained on small plots such as those of the religious orders who, through their monasteries, were the first to introduce agriculture based on non-American species. The indigenous communities maintained this tradition in their family fruit and vegetable gardens and on their cultivated land. Several colonial historical sources explained the ecological and social alterations brought about by the introduction of new crops and livestock into the indigenous agriculture and economy. It was customary and a very common practice among the indigenous populations to mix introduced crops with native crops. Consequently, the biodiversity and abiotic elements of the ecosystem were protected.

In the documentation on tributes, *encomiendas,*[1] allotments and *haciendas,* only isolated cases are mentioned in which the seeds of crops from the Old World were handed over. In colonies directed from the Iberian Peninsular, we know of attempts by the Spanish crown to introduce such crops as wheat, barley, rye, olive trees and sugar cane. Except for the latter case, which was an important economic stimulus, these crops seemed to fare no better than American products. It actually proved more efficient and convenient to pay homage with indigenous products than with exotic products.

Wheat, for example, was sown on maize fields or close to land given over to livestock. In the Caribbean or on tropical lowlands, it prospered only occasionally while, in areas with a long agricultural tradition, such as the Andean high plateau and Mesoamerica, it did not manage to displace maize – which it did, however, on borderlands inhabited by hunters and gatherers. These zones were found in semi-arid or arid areas where the climate was favourable but labour was difficult to find, since such zones were sparsely populated and their inhabitants were nomads who lacked an agricultural tradition. Hence, for the most part these areas were populated with indigenous people from other regions and Europeans. The olive- and vine-growing areas were similar in character. These crops, like many from the Old World, were introduced by religious orders in the middle of the sixteenth century. Some crops that were important for the Spanish economy were imported into America in later periods with negative results for the mother country, as occurred in New Spain with indigo,

[1] Land and inhabitants granted to Spanish colonists by royal decree.

flax and hemp which were unable to become established.

Most of the crop displacement seems to have taken place in modern times, especially since the second half of the nineteenth century, by which time the former Spanish and Portuguese colonies were independent countries and capitalism and commercial agriculture were expanding.

It is interesting to note that 500 years after the discovery of America, in the pre-Columbian traditional agricultural regions of the highlands (Mesoamerica and the Andean region), European crops do not display the qualities normally attributed to them and by virtue of which their use has been advocated for centuries. On the contrary, their failure to adjust to the climate, their susceptibility to pests and diseases, the competition with native products, their insufficient quality, low acceptance by the aboriginal populations and, more recently, their poor compatibility with industrial products are factors which have discouraged their exploitation, thereby emphasizing the marginal or non-existent role frequently played by exotic plants in local production.

The situation is very different in the sparsely populated arid and semi-arid borderlands where colonization principally began in the seventeenth century. Here, livestock production as well as, to a lesser extent, the cultivation of European cereals and – although only exceptionally – vines and other introduced crops, were converted into major activities, thus resulting in a countryside similar to that of the Iberian Peninsula.

The history of agriculture in the tropical areas after the conquest consists in the struggle of pre-Hispanic crops and the traditional agricultural systems – especially slash-and-burn clearing – against livestock production and plantations, regardless of whether the commercial crops were native or introduced (sugar cane, cotton, prickly pear for cochineal, and then coffee, banana, henequen, tropical fruits, stimulants, etc.).

No substantial advances are evident in the development of agricultural technology as regards the methods and instruments that arrived in America from the end of the fifteenth to the middle of the sixteenth century. From the time of colonization to the present, both the mining centres and the urban centres have demanded predominantly American products. In American countries with a strong indigenous influence there may be vast expanses devoted to introduced crops, but native flora and crops also play a considerable role.

In areas that formerly had dense Indian populations, there is in the best of cases a syncretism between the pre-Hispanic agricultural traditions and those of Iberia, resulting in a mixture of products of local and European origin for use in food, clothing, medicine and ceremonies.

CAUSES OF THE MARGINALIZATION OF USEFUL PLANTS

Marginalization is a complex phenomenon that requires a multidisciplinary analysis: however, its general causes are biological, agricultural, cultural and economic in nature.

Biological and agricultural causes

Agricultural methods. Plough and draught animals were the most revolutionary introductions to agriculture, since they enabled it to expand through wide fertile areas of heavy soils such as El Bajío and many valleys of northern Mexico. New irrigation facilities also appeared.

Another fundamental innovation was the introduction of livestock. With European colonization and extensive interbreeding, vast areas based on the practice of hunting and gathering were transformed into agricultural-livestock zones, which most certainly caused the marginalization of plants that were gathered in earlier times by hunters who were in large measure exterminated.

The introduction of many plants was accompanied by a technology to facilitate their cultivation, either because of the specific agricultural practices they required or because their care demanded less time. These qualities were generally not found in native crops, which needed a great deal of attention and were labour-intensive.

The American Indians liked to experiment and use many plants and they therefore tended towards mixed cultivation. The result was that several introduced crops were combined with native crops, especially on family vegetable plots. The Indians also favoured ecological complementarity, in other words cultivation in different environments.

Length of life cycle. Owing to the climatic differences with the Iberian Peninsula, in the majority of the different regions of America it was impossible to adapt perennial species, in spite of the repeated efforts to introduce the vine, olive tree, fruit-trees and other arboreal species. Instead, in various areas and from early times green vegetables and other short-cycle herbaceous plants introduced by the Europeans prospered. This allowed the sufficient cultivation – especially during the cold season – of such crops which were of limited availability in America. It was possible to introduce without too much difficulty small-grain cereals, rice and other annual crops with an average cycle.

Adaptation of introduced crops. The distribution and unit yield of the world's current major crops show that domesticated plants frequently reach their optimum yield in a place that is very different from its origin. It is sufficient to consider the development in Latin America of crops such as coffee, banana, citrus fruit, soya and various grasses. This phenomenon can be explained by the initial absence of pests and diseases in the place where they have been introduced. The neglect of American native plants became more acute in the nineteenth century and was basically due to socio-economic causes and, to a lesser extent, the failure of varieties originally introduced to adapt. Only when these plants had developed under domestication were they able to expand extensively. Proof of this is the existence of specific American ecotypes of many of the plants introduced, which have played a fundamental role in production and in local plant improvement programmes.

Major obstacles had to be overcome to introduce crops even into areas very similar to those of southern Spain, a region which was of fundamental importance in the transfer of a Mediterranean agriculture to America. There were enormous difficulties in acclimatizing barley, wheat, vine, olives and fruit-trees in locations with a climate very similar to that of Andalusia and Estremadura or southern Portugal, whose biological and social conditions were very favourable. When New Spain became independent, European crops were already well established in this part of America.

Nowadays, chemical synthesis has displaced some natural products: synthetic vanilla has caused a reduction in the cultivation of vanilla, for instance, while synthetic anilines have replaced erythoxyline, derived from campeachy wood.

Cultural causes

The pre-Columbian indigenous societies had managed to meet a certain amount of their requirements in food, clothing, health and tools, etc., so the adoption of some European products and the consequent abandonment of native products took a long time. Even at present it frequently happens that indigenous communities mainly resort to native plants, while they grow introduced plants or rear livestock for the market or for food on special occasions. Rather than displacing the use of American products, the adoption of European products has complemented them in gastronomy, medicine and religious ceremonies, for example, which are generally the result of cultural syncretism.

The colours and flavours or textures of the Old World's plants satisfied the indigenous communities' demands. In several parts of America, vegetables introduced by the Europeans were assimilated very easily. Indeed, certain non-American plants contained colours with a symbolic importance and, moreover, coincided with the food habits of the indigenous peoples.

An important cultural factor was the role of the African cultures and their effect on agriculture: the slave trade brought crops of African and Asian origin, for instance.

Catholicism was integrated into various Amerindian religious currents, which explains why exotic and native plants were grown to meet the requirements of the indigenous Catholic ritual. Religious orders encouraged the introduction of crops; the use of American magical plants or amulets was prohibited and they were replaced by European ones. Utilizing Old World plants, using horses, carrying a sword or dressing in a European way were cultural signs which conferred prestige. These uses and habits mainly influenced the indigenous nobility, such as local rulers or traders.

Economic causes

Most frequently, the reasons for the neglect of a native or introduced species that was ecologically and agriculturally adapted to a region were socio-economic. Underdevelopment was one of the main reasons for the existence of many neglected species on the subcontinent. The low purchasing power of the vast majority of the population diminished the market of many products, which subsequently disappeared or were marginalized. This does not mean that economic development necessarily leads to a more diversified agriculture. Rather, with the economic improvement of a region or country, or with their entry on to the international market, some marginalized plants, whether native or introduced, may be converted into major crops (prickly pear for the cochineal berry, indigo, cereals, fruit-trees, henequen, etc.). The transformation of traditional agriculture into commercial agriculture generally results in the specialization of production, with the cultivation or utilization of many species being abandoned. The paradox of underdevelopment is that it prevents certain crops from finding an adequate market, which is why they are kept by the Indians to meet possible personal or collective needs. However, with economic development some of these neglected plants do find a market, or their market is widened, while many others disappear and various crops that were previously important may even become marginal owing to the monetarization and proletarianization of the peasant farmers.

Economic and agricultural transformations are related to factors such as considerable changes in the size and distribution of the population; the development of infrastructure (especially communication routes, irrigation and produce storage systems); land occupancy, the marketing of products and agricultural inputs; industrialization; the financing of production; and consumption patterns.

It is known that after the conquest there was a collapse and partial relocation of the population in Latin America, which certainly brought about changes in the plants used. The demographic upset was not only quantitative, as it particularly affected the indigenous aristocracy who were the repository of the culture and, therefore, of the use of many plants for specific purposes such as medicines, rituals and decoration. Until the seventeenth century, the population made no significant recovery and colonial cities developed in old indigenous regions as well as around congregations, missions and mining centres. Until then, there was an accelerated development in introduced crops, above all to meet the demands of the population of European and mixed origin.

A key to understanding the slow adoption of a European lifestyle in America is to consider the low number of the white population, compared with the millions of the native population. The former is estimated to have been 849 000 around 1650, while the indigenous population is calculated to have been 10 035 000 and the black, mixed and mulatto population 1 527 000.

The conquest and colonization resulted in the partial destruction of many hydraulic works, medicinal plant gardens, schools, etc., which possibly caused the marginalization of many plants without their immediate replacement by other European plants. The building of infrastructure was only significant at the end of the sixteenth century. In the area of botany, Francisco Hernández collected and studied Mexican plants between 1570 and 1577. Under the Bourbons, science and technology received a great impetus and Spanish botanical expeditions to America were organized, although these seem to have had little effect on agriculture and the plants used.

Changes in land occupancy are fundamental to an understanding of the marginalization or expansion of certain plants. However, it is known that the motive behind the expropriation of indigenous land was generally not to turn it over to exotic crops, but rather to oblige payment for the hire of native products or services and to channel labour forcibly towards mining, livestock rearing, building, etc. However, the Spanish and Portuguese crowns were obliged, because of their own interests, to limit the expropriation of indigenous communities' lands and, in doing so, they protected agricultural traditions while also halting the marginalization of native plants.

The expansion of livestock rearing led to very profound changes in land use. It brought fodder and crops such as wheat, barley and rice. A great deal of land was originally devoted to livestock rearing and then to the farming of introduced plants. These changes are well documented in both South and North America as well as, to a lesser extent, in the Caribbean.

The marketing, industrialization and financing of agriculture were limited during colonial settlement, so they did not have much influence on the choice of plants grown. Tributes, taxes and religious contributions certainly had an effect on the changes in cultivation patterns, particularly when they were demanded in coin. However, payment in kind with native products was generally permitted.

The policy of the Spanish and Portuguese crowns on colonization made it obligatory by royal decree for colonists to take plants from their region to the New World (Santa Fe de Bogotá, Puebla de los Angeles, Huancayo etc. were places in America where this type of obligatory introduction was practised). Cities were thus created which imitated as far as possible those of the Iberian Peninsula.

CONCLUSION

The situations presented here are the most manifest; through the period of discovery, conquest and colonization, Latin America experienced an evident case of agricultural cross-breeding, although each region responded in different ways to the arrival of plants from the Old World. One only has to reflect on the elimination of indigenous populations; epidemics and famine are well documented for the three main vice-royalties: New Granada, Peru and New Spain. European agronomic culture did not develop in major sectors of the indigenous population, except in small areas where there was no culture with an agricultural tradition or in those where the population accepted the changes with ease.

TABLE 2 Plants marginalized as a result of Old World crops

Species	Common names
ARID AND TEMPERATE ZONES OF NORTH AMERICA	
Asimina triloba	Papaw, pawpaw
Cyrtocarpa procera	Chupadilla, jocote
Diospyros virginiana	Persimmon, kaki
Gossypium hopei	Arizona cotton
Helianthus tuberosus	Jerusalem artichoke
Myrtillocactus geometrizans	Garambullo
Opuntia spp.	Prickly pear, tuna
Panicum sonorum	Arrocillo
Phellopterus montanus	Gamote, pastinaca de monte
Photinia arbutifolia	Holy fruit (fruta santa)
Ribes grossularia	Gooseberry
TROPICAL LOWLANDS AND THE CARIBBEAN	
Aniba roseodora	Palo rosa
Annona cherimola	Cherimoya, cherimoyer, chirimoyer, custard apple
Annona muricata	Soursop, guanabana, graviola
Annona reticulata	Bullock's heart, sugar apple, custard apple
Calathea allouia	Topinambour, topitampo, topi-tamboo
Dioscorea trifida	Cush-cush, yampi yam
Helicornia bihai	Platanillo or "wild banana"
Malpighia glabra	Acerola, azarole
Maranta arundinacea	Arrowroot, Bermuda arrowroot
Monstera deliciosa	Ceriman, cheeseplant
Pachyrhizus erosus	Yam bean, manioc bean, jícama
Platonia insignis	Bacury, bakuri guiana orange
Pouteria campechiana	Canistel
Xanthosoma sagittifolium	Tannia, tania, yautia, new cocoyam
MESOAMERICA	
Amaranthus hypochondriacus	Prince's feather
Bixa orellana	Annato, arnatto, roucou, achiote, bixa
Byrsonima crassifolia	Nance, golden spoon
Casimiroa edulis	White sapote, Mexican, casimiro apple, matasano apple
Crescentia alata	Cirian, tecomate

TABLE 2 (cont.)

Species	Common names
MESOAMERICA (cont.)	
Cucurbita ficifolia	Cidra, sidra, chilacayote, Malabar gourd
Dahlia excelsa	Dahlia
Diospyros digyna	Black sapote, Indian ebony persimmon
Indigofera suffruticosa	Anil, indigo plant
Manilkara zapota	Sapodilla (plum), chiku, chicle, naseberry, beef apple
Phaseolus acutifolius	Tepary bean
Pouteria sapota	Sapote, marmalade plum, mammee zapote
Spondias mombin	Yellow mombin, jobo, taperebá
ANDEAN REGION	
Arracacia xanthorrhiza	Arracacha, apio, Peruvian parsnip
Bertholletia excelsa	Brazil nut, Pará nut
Canna edulis	Achira, Queensland arrowroot, tous-les-mois
Fragaria chiloensis	Pine strawberry, pineapple strawberry
Lepidium meyenii	Maca
Oxalis tuberosa	Oca
Passiflora ligularis	Sweet granadilla
Solanum phureja	Andean potato (papa andina)
Tropaeolum tuberosum	Mashwa, añu
Ullucus tuberosus	Ullucu, oca quina

The process of marginalization in the nineteenth century was no clearer; the agricultural pattern remained constant in spite of the collapse of the dominant population sector. The independent Latin American countries depended on other nations looking for commercial products; the United Kingdom, France, Germany and the United States dominated the agricultural sector. The plants cultivated were those demanded by the growth of modernization, which caused a greater specialization but left room nevertheless for American crops of which the agricultural landscape was previously composed.

Faced with the current ecological crisis, it is not surprising that the countries advocating reductionist policies in the handling of germplasm, which are the same countries that brought about the marginalization of crops, should be the first to want to restore biodiversity.

Consideration is now given to how several crops were wiped out, mainly in areas where populations and indigenous cultures disappeared; it is worrying that, in the tropics, deserts or temperate zones, not even the peasant framers have any recollection of certain plants that were once cultivated.

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Agriculture in Mesoamerica

Domesticated plants and neglected crops in Mesoamerica

"In southern Mexico and Central America, the plant researcher finds himself, in the full sense of the term, in a veritable centre of creation."

(Vavilov, 1931)

Mesoamerica was defined by Paul Kirchoff in 1943 as the area of influence of Mexican cultures in the pre-Columbian era. Its boundaries are of course wide: the basins of the rivers Pánuco and Santiago mark its northern limit while its southern border runs from the Atlantic coast of Honduras along the Pacific slope of Nicaragua and the Nicoya peninsula of Costa Rica. In addition to being a cultural region, Mesoamerica is one of the areas of origin of agriculture, comparable with the Near East, China and the Andean region. Vavilov considered it to be the continent's most important "centre of origin" – nowadays referred to as centre of genetic diversity.

PHYSICAL GEOGRAPHY AND HUMAN OCCUPATION

Mesoamerica is a region of complex physical environments. Starting from the centre of Mexico, two mountain ranges stand out. They are the Sierras Madres, which run parallel to either coast and extend along other mountain axes, some of them with very active volcanoes, from the centre of Mexico to Panama. Between the ranges in Mexico, there are extensive, fairly flat and dry areas rising up to the central valley. Towards the southern end of the region, there are intermountain depressions and valleys which are intersected by rivers. The result is a very complex relief. Between the ranges and the coast, alluvial plains and the Yucatán peninsula spread out over limestone rock.

Mesoamerica's position, between the Tropic of Cancer and lat. 10°N places it in an area affected by great climatic forces originating in the surrounding oceans. The interaction of the climatic elements, latitude and relief creates a variety of environments, ranging from the coastal plains of the Atlantic, with a precipitation of 3 000 to 5 000 mm, to the semi-arid areas of Mexico. The region is principally divided into zones with continuous humidity on the Atlantic slope and zones with alternating seasons, including a dry period, on the Pacific slope. This period corresponds to the northern winter, which the Spanish called summer. The area with alternating seasons, which stretches from the Pacific coast to the mountain heights, was the first to be occupied by humans and is still the area with the greatest population density.

The plant cover is also very varied in Mesoamerica since the elements of northern origin – pines reach as far as Nicaragua, for instance – merge with South American species, many of which have penetrated deep into the lowlands of both slopes in Mexico. Under these conditions, isolation and selection have naturally created a high level of biological diversity and consequent endemism. As in other tropical areas, the main

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landscapes are determined by the interaction of climate and relief, soil factors being of lesser importance.

The current landscape of Mesoamerica is defined by human occupation. In general, it gives the impression of a rather dry, highly eroded region, with original plant cover localized in small isolated spaces. Of the subdeciduous forest which covered the region from Sinaloa to Guanacaste, only small areas remain, some in Mexico and others in Costa Rica. In most of the countries, the agricultural boundary has broken down and the humid tropical forests are being reduced at such a rate that within ten to 20 years they will have disappeared.

PAST CULTURES

The first inhabitants of Mesoamerica were immigrant groups from the north who advanced towards South America and formed small nomadic communities about 25 000 to 40 000 years ago. The first traces of utensils appear about 18 000 years ago and the first culture known was that of the Olmecs, a conglomeration of populations which extended from the coastal plains of the Gulf of Mexico to the highlands. A series of cultures, which occupied different areas and had separate periods of development, succeeded one another in Mesoamerica. There are remnants of their complexity and origins in the indigenous languages, which appear to be ancient and profound ramifications of a few basic stocks of North American origin. Some of the successive cultures became fully developed, progressing from settlements to empires. When the Spaniards arrived, Mesoamerica was not dominated, as were the Andes, by a hegemonic power. The Aztec empire coexisted alongside tiny independent tribes but the Aztecs were the chief power and their language, Nahuatl, virtually became a lingua franca throughout Mesoamerica. Plants, equipment for their cultivation and use and even soil types had Nahuatl names which were used from Sinaloa to Costa Rica, and some beyond the frontiers of Mesoamerica.

AGRICULTURAL SYSTEMS

Agriculture was the basis of the Mesoamerican civilizations. It is estimated to have taken centuries to develop and its final stage – which became known to Europeans in 1500 – is thought to have been the result of an accumulation of practices and materials invented and perfected by the various cultures that had survived wars, famines and natural disasters. It cannot be assumed that this result was a linear process; it must have taken shape slowly in centres of economic and political power, expanding or contracting according to the fate of the human groups. Efforts to improve crops and invent production and utilization practices were undertaken more or less continuously and were perhaps safe from many hazards because activities were in the hands of farmers, who were the least affected by power changes.

From gathering plant products, people went on to protecting and cultivating certain plants. It is thought that fruit-trees, which supplied a good part of the produce gathered, were also the first species to be protected and cultivated. During the expedition to Honduras, the Spaniards of Cortés managed to survive thanks to the sapodillas which they found in the forest. One could imagine that the primitive seed plantings were similar to the ones that can still be seen in the plots of houses in some parts of Chiapas and Guatemala. These plots are a mixture of fruit-trees, edible and medicinal plants, cocoa and ornamental plants, sown and harvested without any order under native trees which serve no other purpose than to provide fuel and shade. There is nothing to indicate that selection was practised under these conditions, nor that the types chosen were sown. In dry regions, primitive sowings could have been based on plants that produce seeds and

FIGURE 2

Mesoamerica

require clean soil to grow. Eventually, the system of slash-and-burn clearing developed, and this is practised in all regions, especially those with alternating seasons.

Another line of development was the control of soil humidity. Irrigation dates back to ancient times in Mesoamerica and, in the central valley of Mexico, it was practised over very extensive areas using different systems. They did not reach the point of constructing engineering works as in Peru, but they did manage to cover sufficient areas to supply the big urban centres of Teotihuacán and Tenochtitlán. Major irrigation development began in the colonial period with the cocoa plantations, which extended this crop to new areas such as the Pacific lowlands as far as Sinaloa. In an opposite process, drainage systems for wet soil were invented, based on the construction of terraces. The most spectacular were the *chinampas* of the valley of Mexico, now reduced to a tourist attraction. They made a considerable contribution to Mexico City's food supplies before the conquest and during the colonial era. In the low-lying lands of Campeche and Veracruz, terraces were used from the time of the early cultures and were also developed on the lowlands occupied by the Mayas.

The development of agricultural systems depends to a great extent on labour implements and the availability of animal traction. Mesoamerica did not make a special contribution to either of these, however. Only the most primitive farming equipment was known: the *coa*, a pointed stick for sowing seed, was in general use; in Mexico, *coas* and bronze spades were invented while, in other parts of the region, large shells were used for this purpose but no tillage implements were developed as they were in the Andes. The complete lack of draught animals was characteristic of the entire New World. Human resources provided the necessary energy while slavery, whether concealed or evident, enabled the dominant groups to acquire food, clothing and adornments through tributes. Regarding cultivation systems, methods and equipment, Mesoamerica did not contribute any new or special item that was not already known in other agricultural systems.

Among the Mesoamerican agricultural systems, that of the Mayas has received most attention. Much has been written in an attempt to understand how, in an extremely unfavourable environment with very poor soils and very abundant or scarce rainfall, a culture could develop whose advances in mathematics, astronomy and architecture were superior not only to those of other pre-Columbian cultures, but also contemporary European and Asian cultures. The construction of major urban centres must have required a great number of workers, and the subsistence of the latter and of the ruling classes cannot be explained satisfactorily by the region's current agricultural production system. Although partial theoretical explanations have been put forward, the question is still far from being resolved. It is known that the Mayas depended on three basic products – maize, beans and gourds – as well as minor products, all of which were Mesoamerican. It has been argued, without any reliable evidence, that it was they who domesticated cocoa, although it has been proved that they prepared a kind of chocolate. Two other plants used and probably sown were *Brosimum alicastrum* (breadnut or ramón) and *Talisia* spp., both fruit-trees. When the Europeans arrived, the Mayan culture had disappeared almost completely. Their descendants, particularly in Yucatán, practise a system of agriculture that does not seem to have changed much since the classic era.

DOMESTICATED PLANTS

It would be too academic an exercise to classify the plants of Mesoamerica according to their process of domestication into tolerated, cultivated and domesticated species as if these were distinct categories because plants occur in all the intermediate states as well. It has not been possible to identify the factors that allowed their domestication, but some must be the same that favoured domestication in the Near East, Southeast Asia or China. On many occasions it has been stated that this process occurred at more or less the same time throughout the world but that it was slower in Mesoamerica.

The information available on domestication covers aspects such as botany (the existence of a great species diversity and of wild relatives), archaeology (plant remains, representations or impressions on utensils) and history and linguistics (documents, names in indigenous languages). Archaeological proof carries the greatest weight but is restricted to those species and regions whose conditions have favoured the preservation of organic remains and therefore allowed a correct identification and reliable dates to be given. Consequently, the information derived from archaeological evidence in Mesoamerica and in other regions of primitive agriculture must be gathered within these limits. Excluded are those species which do not preserve well and areas of high humidity which, according to Vavilov, might have been those with the oldest forms of agriculture.

Although Mesoamerica did not make any valuable contributions to cropping systems, in the domestication of plants its place is comparable to that of any other region, both in the number and importance of species domesticated. It is an absolute certainty that maize was domesticated in Mesoamerica and that, from the time when agriculture was first practised (about 3 000 years ago), it already formed part of the earliest production systems along with a species of *Cucurbita* and *Capsicum*. With regard to maize, archaeological evidence discovered by MacNeish in Tehuacán, central Mexico, constitutes the most complete proof of the local evolution of a crop. In Mesoamerica, numerous variants or races were developed which adapted to almost all environmental conditions, from sites with high humidity and temperatures to areas at a height of 3 100 m with a cold, dry climate.

Mesoamerica can be credited with having invented the greatest number of ways of eating and drinking maize products as well as the equipment and methods for preparing them. Lime was used to separate the husk from the grain, which increased its protein value and produced a top-quality food. This was definitely a chance discovery which was not applied in other regions of the world. Among the uses of maize in Mexico, in 1520 Hernán Cortés cited the production of canes "which are as sweet and honeyed as sugar cane".

At least three species of *Cucurbita* originated in Mesoamerica: *Cucurbita argyrosperma*, perhaps the first to be cultivated, which is suited to altitudes between 0 and 1 500 m; *C. moschata*, the most common and useful, which is found between 300 and 1 500 m, and *C. pepo*, which is less important in Mesoamerica than in Europe and the United States and which grows up to an altitude of 2 000 m. A fourth species, *C. ficifolia*, is eaten in a different way from the others and may also originate in Mesoamerica.

Among the cucurbits, two species of *Sechium* are also grown: *Sechium edule* (chayote), whose fruit, roots and tender stems are eaten and whose distribution is very wide in the American tropics (its centre of origin is Mexico and Guatemala); and *S. tacaco*, although this is restricted to its original area, the highlands of Costa Rica.

The tomato (*Lycopersicon esculentum*) was first known in Mexico, where it was described in detail by Francisco Hernández around the period 1571 to 1577. It was not of great importance as a vegetable, as it was an extra plant in the maize fields, although its fruit was the size of modern varieties.

A vegetable with a similar use is *Physalis philadelphica*, commonly called tomato or husk-tomato in Mexico; it is also grown in Guatemala and a few varieties of it are preserved.

The Mesoamerican species of chili, *Capsicum annuum*, from which peppers are derived, has wild populations and a very broad varietal diversity in this region.

The common bean, *Phaseolus vulgaris*, appeared about 5 500 to 7 000 years ago in central Mexico where wild populations of it abound, but intensive cultivation of it began between the first and seventh centuries. *P. coccineus*, a perennial species of high ground, was already to be found in Mexico about 2 200 years ago; another very similar species, *P. polyanthus*, is grown together with *P. coccineus*; and *P. acutifolius*, which was grown about 5 000 years ago in Tehuacán, extends from the United States to Costa Rica.

One of the main crops of pre-Columbian Mexico was *Amaranthus hypochondriacus*, whose seeds were eaten in the same way as cereals. Another species cultivated, especially in Guatemala, is *A. cruentus*.

Native roots and tubers have not been important in Mesoamerican agriculture. The yam bean (*Pachyrhizus erosus*) is an ancient crop which is nowadays very widespread. The potatoes of Mexico's highlands, of great value as an energy food, produce small edible tubers but are not cultivated.

Cacao (*Theobroma cacao*), which is found growing wild in southern Mexico, was possibly domesticated in this region where there are aberrant varieties, and its pre-Hispanic cultivation did not go beyond the present frontier between Costa Rica and Panama.

Upland or hairy cotton (*Gossypium hirsutum*) is the most extensively grown fibre plant; one of its centres of domestication seems to have been the Gulf of Mexico and archaeological remains in that country indicate that it was known about 5 500 years ago. Other fibre plants, today replaced to a great extent by synthetic fibres, are henequen (*Agave fourcroydes*), sisal (*A. sisalana*), *A. angustifolia* var. *letonae* of El Salvador and several species of *Furcraea*.

Of the leaf vegetables, mention should be made of *Crotalaria longirostrata*, *Solanum americanum*, *S. wendlandi*, *Cnidoscolus chayamansa*, *Chenopodium berlandieri* spp. *nuttalliae* and *Opuntia leucantha*, which are eaten fresh or cooked, as well as the tender stems of *Cucurbita* and *Sechium* species. The inflorescence of *Chamaedorea tepejilote* (pacaya) is a widely consumed item in Mexico and Guatemala, but its cultivation is still limited to kitchen gardens. The chayote (*Sechium edule*) is used for its fruit, roots and tender stems.

Probably the majority of domestications has occurred with fruit-trees. Archaeological remains of some of them exist, although it is not known with any certainty whether they were gathered or cultivated. *Annona diversifolia*, *A. reticulata* and *A. scleroderma* are natives of Mesoamerica and wild populations of some of them are known; *Casimiroa edulis* is cultivated from sea level up to 2 500 m; archaeological remains dating back 5 000 years have been found. This is a complex species because of its different local populations. *Couepia polyandra* and *Diospyros digyna*, exhibiting numerous varieties, grow wild from Mexico to Costa Rica and also date back about 5 000 years. *Inga jinicuil* and *I. paterno* originate from Mexico and El Salvador, respectively. *Licania platypus* is found from Mexico to Panama; *Manilkara zapota*, with numerous varieties, is now grown in all tropical areas. *Persea americana*, the avocado pear, is one of the fruits which, in Mesoamerica, are grown at any altitude between 0 and 2 500 m; wild populations of this plant still exist. The following also grow: *Parmentiera edulis*, *Persea schiedeana*, *Pouteria campechiana*, *P. sapota*, the sapote and a related population, *P. viridis*; *Pouteria hypoglauca*, *Prunus capuli*, *Psidium friedrichsthalianum* and *Spondias purpurea*, with many varieties and uses. In Mexico, there are numerous wild cactus species whose fruits are gathered and there is an incipient cultivation of a few species.

Spices and condiments include *Capsicum annuum* and *C. frutescens*; *Pimenta dioica*, which grows wild from Mexico to Costa Rica and whose cultivation dates back to ancient times; *Vanilla planifolia*, produced more outside the region; and *Fernaldia pandurata*. Some spices are obtained from semi-wild plants, such as *Cymbopetalum penduliflorum*, chufle (*Calathea* sp.) and *Quararibea funebris*.

Fermented drinks (pulque) or fresh drinks (maguey juice) were known in the pre-Columbian period and are obtained mainly from two species of *Agave*, *A. salmiana* and *A. mapisiga*. The origin of the preparation of distilled drinks (mescal, tequila) obtained from *A. tequiliana* and other species also dates back to that period.

There are a great number of medicinal plants, most of which are in the early stages of cultivation. Mesoamerica's most recent contribution has been the *Dioscorea* species which is used for the production of diosgenin-cortisone and is grown for this purpose in Mexico.

No less important are ornamental plants. The Spanish found gardens in Mexico similar to those of Europe and, in the centuries following the conquest, numerous species of orchids and bromeliads from Mesoamerica have been grown in Europe and the United States. A group of Compositae, *Ageratum*, *Cosmos*, *Dahlia*, *Tagetes* and *Zinnia*, which were cultivated in the region from the pre-Hispanic period, have been intensively selected in Europe and the United States. Wild populations are to be found of all of these genera as well as of *Tigridia*, *Zephyranthes*, *Euphorbia* and other ornamentals.

MARGINALIZATION OF CROPS IN MESOAMERICA

Of the causes which contributed to the neglect of certain crops, the replacement of a natural product by a synthetic one has perhaps been the most drastic. The indigo (*Indigofera* spp.) agro-industry, which still has a great commercial importance, has now almost been entirely displaced by the production of chemical dyes, while *Agave* and *Furcraea* have been replaced by synthetic fibres. The rubber plant (*Castilla elastica*), whose use was already known in pre-Hispanic times, was a budding crop at the turn of the century but it was then replaced by a more efficient plant, *Hevea brasiliensis*, which was in turn replaced by synthetic rubber.

In food plants, marginalization has been a longer and less straightforward process. Culinary preparation and eating habits instilled from childhood have resulted in the permanence of these species. However, violent social changes such as the conquest brought about profound alterations. Indigenous products were replaced by introduced products which competed with the former and were favoured by the prestige attached to them by the dominant social group. Indigenous crops were abandoned first of all by the upper social strata and then by the lower strata. Only the very poor communities and indigenous populations maintain the traditional crops as well as the methods for handling and using them.

The change, based on social prestige, occurred without taking into account the intrinsic value of the crops, for instance their nutritional properties or production costs. In El Salvador, a comparative study between native vegetables, such as chipilín or tachipilin (*Crotalaria* spp.) and hierba mora or nightshade (*Solanum americanum*) and European vegetables (lettuce, cabbage), showed the superiority of the former as sources of vitamins and amino acids, not to mention that their production requires less care and costs for fertilizers and insecticides.

The non-acceptance of a crop because of its lack of social prestige is reflected in many aspects. Growers in Guatemala can obtain credit on their citrus fruit but not on such a prized local fruit as the papausa (*Annona diversifolia*), in spite of the fact that the latter has a good market. Moreover, there are no extension services for native crops, perhaps because a knowledge of them is part of the heritage of the indigenous people.

Many foreign technical experts concentrate on exotic crops and not on native ones, as their experience, information and extension equipment relate only to the former. On the other hand, it is frequently foreign anthropologists who draw attention to native crops and, in particular, to the processes known to the indigenous communities regarding their use.

There is one interesting case of marginalization, that of huautli or prince's feather (*Amaranthus hypochondriacus*), which is dealt with in a later chapter.

Numerous Mesoamerican crops have not expanded beyond limited areas. The chaya or spurge (*Cnidoscolus chayamansa*) is cultivated in Yucatán and Petén; the ixtlán (*Solanum wendlandi*) in southeastern Guatemala; the loroco (*Fernaldia pandurata*) in El Salvador; the huauzontl (*Chenopodium berlandieri*) in central Mexico. There are local studies on agronomic handling of most of these plants and it is possible that some might expand to new areas.

The future of neglected crops in Mesoamerica depends on the combined action of several factors. One is research on production and handling, aimed at obtaining superior varieties and improved agronomic practices, especially in protection against pests and diseases. Another is establishing reliable and permanent sources of seeds and other propagating material and making them available to growers. Fundamental to this process are agricultural extension campaigns that show the advantages of the neglected crops over exotic ones as regards their nutritional value and ease of production.

These aspects require intensive study and an evaluation of varieties, traditional production systems and ways for indigenous groups or rural workers to utilize the products in order to adapt them to modern methods. Furthermore, a study must be made of market conditions and the possibilities of widening the market to other regions, while research should be done on the way the product is presented as well as on the standards which guarantee the consumer a stable quality and promote a wider acceptance. The diversification of uses in agro-industries will create new market possibilities and provide a guarantee for the producer.

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Beans
(*Phaseolus* spp.)

Of the genus *Phaseolus sensu stricto,* which includes 55 species, five have been domesticated. The pre-Columbian peoples grew them for thousands of years as a main source of protein, since animals did not have an important role as a source of food or draught power, particularly in Mesoamerica.

As early as the pre-Columbian period, the kidney bean (*P. vulgaris* L.) had gained wider acceptance and was selected more intensively. The early chroniclers inform us that, in the Aztec and Incan empires, great importance was given to this species and it was used to pay tributes. It gained even more popularity after the conquest and, from 1880, with the exception of isolated studies the work on genetic improvement was mainly concentrated on this bean. This preferential treatment was detrimental to the other species which are of greater or comparable interest in modern agriculture, at least in areas that do not offer optimum ecological conditions for their development.

The ancestral form of *P. vulgaris* grows within the boundary between two climatic zones – subtropical dry and tropical temperate – where pre-Columbian societies established many settlements, a fact which may explain the acceptance of the species. To cover the greater part of the area occupied (except for certain Andean regions), the Pre-Columbians domesticated four other species.

The five ancestral forms were lianas which grew in different ecological niches. Biochemical studies have shown how *P. lunatus* was domesticated in several points of Mesoamerica and *P. vulgaris* in the Andes. Except in the latter region, uniformity in selection pressure led to a considerable similarity in evolutionary stock. With the exception of the tepary bean, the association with maize – although it was late in the Andes – also contributed to this standardization. The levels of evolution of the five species have been varied and there is a great potential for exploitation; for example, as regards the growth habit in *P. polyanthus* and the size and colour of the *P. acutifolius* seed. The ecological potential of these species would enable some of them to be developed even more profoundly than *P. vulgaris*.

At a time when the model of an agriculture which is both sustainable and productive has been accepted, beans deserve to be given renewed attention.

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Phaseolus coccineus

Botanical name: *Phaseolus coccineus* L.
Family: Fabaceas
Common names. *English:* scarlet runner bean; *Spanish:* ayocote (name of Nahuatl origin, central Mexico), patol (Mexico [Zacatecas]), botil (Mexico [Chiapas]), chomborote, piloy (high plateau of Guatemala), cubá (Costa Rica)

This species has been cultivated in the high parts of Mesoamerica for many centuries. In pre-Columbian Mexico, the people of the Anahuac cultivated it extensively and ensured its distribution. Its introduction into southern Colombia (Antioquia and Nariño) and Europe (where it is known as scarlet runner bean and haricot d'Espagne) could have occurred in the seventeenth century before reaching other parts of the world, such as the Ethiopian highlands. It has been found in archaeological remains only in Mexico, in Durango and Puebla, and wild only in Tamaulipas. Although archaeological information is very scarce, it could be assumed that its Mexican domestication took place in humid high zones.

Changes in maize varieties (earlier-maturing and with softer stems) and the use of fertilizers (for example, urea) and herbicides in maize fields led to the gradual abandonment of this crop in eastern Guatemala and in Costa Rica. It is reasonable to suppose that the same is happening in other areas of its cultivation. Because of its ecological niche, *P. coccineus* has suffered heavy competition from exotic crops with a higher consumption and better market, for instance vetch, broad bean, cabbage, garlic and onion.

P. coccineus has been used in its nuclear area, particularly for its dry or green seeds. The consumption of young seeds enables the crop to be expanded to higher altitudes, since the fleshy root produces a second growth after light frosts (for example in Huehuetenango, Guatemala). The root of this legume has medicinal uses in Mexico and the flowers are also eaten. Its gaudy influorescences may be the reason for its recent expansion as an ornamental plant in Europe and the United States. The green pod is used as a vegetable in western Europe and the dry seeds (white seeds) are eaten in some traditional dishes.

Botanical description

A pluriannual species of great vegetative vigour, with stems of several metres (only in a few modern cultivars are there shrubby forms) which emerge from a fleshy root, *P. coccineus* is easily distinguished by: its large seeds (the weight of 100 seeds is 80 to 170 g and 6 to 12 g for the wild form) and small, narrow, elliptical hilum; and its large influorescences (20 cm and in excess of 20 fruit-bearing stems) with scarlet, white or, more rarely, two-colour flowers. It carries out hypogeal germination, has a fleshy root which is divided and generally fusiform and which allows cotyledonary young shoots to resprout over several consecutive years. It flowers 50 days after sowing, with early varieties, or at the start of the rains, and continues to produce flowers over a long period, except in the shrubby varieties. In the majority of cases *P. coccineus* undergoes cross-pollination, assisted by its extrorse stigma and nectaries and through the action of bees and humming birds. Thus far, it is considered self-compatible.

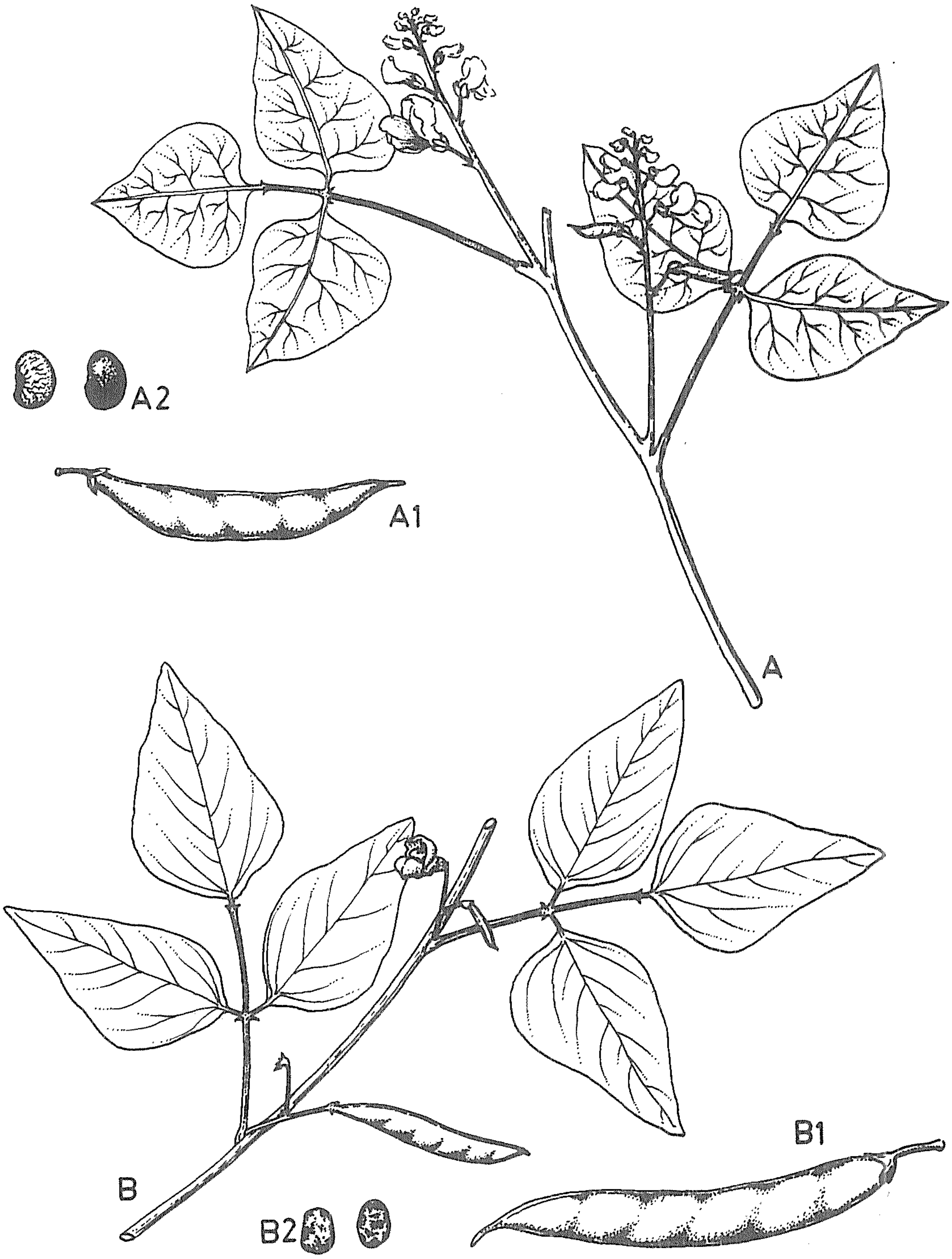
The seed of wild varieties is dispersed through explosive dehiscence of the pods during the dry period. In some wild populations there is a short latency; the seed's viability in natural conditions does not exceed three years.

Ecology and phytogeography

Like *P. polyanthus*, *P. coccineus* tolerates higher precipitations than other species of *Phaseolus*

FIGURE 3

Beans: A) *Phaseolus coccineus*; A1) legume; A2) seeds; B) *P. acutifolius*; B1) legume; B2) seeds



(Table 3), provided that the soil has good drainage; that is with derivatives of volcanic ash, fine particles, etc. It grows at cooler temperatures than other cultivated species and is generally heliophytic, although it tolerates mists.

Its nuclear area extends from Durango to Veracruz and Puebla. In Guatemala, it is traditionally sown on the slopes of the Cuchumatanes range, on the high plateau of Huehuetenango up to Alta Verapaz and Sacatepéquez, and in the highest parts of the rest of Central America. The wild form of *P. coccineus* (although unable to be confirmed as ancestral throughout its distribution) extends from Chihuahua in Mexico to Panama, generally between 1 400 and 2 800 m in the humid high forest.

Genetic diversity

In its wild form, this species displays a great phenotypical variation in its current state of evolution, in contrast with the other wild species of the genus (there is some similarity with *P. augusti* of South America). Wild *P. coccineus* may be considered to be a complex of several forms, now in active speciation, throughout its distribution range. Some very differentiated forms, such as *P. glabellus*, may have become separated, constituting an early form of a group of which it is now difficult to distinguish all the variants. Allogamy is frequent in these plants, and the crossing of wild and cultivated forms, which have been displaced by humans, has changed the speciation patterns. Because of its active process of evolution, this species complex is not an easy task for the taxonomist but, by the same token, it offers great potential for the plant improver.

In addition to a group of four wild forms with scarlet flowers, mention should be made of another four forms with purple flowers. *P. polyanthus* is a related species at the boundary of the primary genetic stock of the scarlet runner bean, since in some cases it can be crossed with the latter, as in Putumayo, Ecuador or in Imbabura, Colombia. Likewise, *P. vulgaris* may be considered to be at the boundary of the primary genetic stock of the scarlet runner bean.

There are only a few definite cultivars, particularly among the climbers; among the indeterminate shrubby cultivars, "Patol Blanco" may be mentioned and, among the determinate shrub cultivars, "Hammond's Dwarf".

There are risks of genetic erosion in areas where the traditional maize field has been changed, as some parts of Mexico (Chiapas, Oaxaca, Puebla and Veracruz), Guatemala and Costa Rica. Along with maize, the three species of bean (*P. coccineus*, *P. polyanthus* and *P. vulgaris*) and gourds were frequently sown in these areas. In the high plateau of Mexico (Durango, Zacatecas), the recent spread of the kidney bean may displace the "patoles" for reasons of cost.

P. coccineus material exists in collections of germplasm, mainly in Chapingo in Mexico (INIFAP), Pullman in the United States (USDA) and Palmira in Colombia (CIAT). The cultivated material has already been collected to a great extent, except in some areas of Guatemala (for example, Quiché), Honduras and Costa Rica, where it may be already too late to make such a collection.

For the wild material, it is necessary to collect around the great cities of Mesoamerica, particularly in the valley of Mexico, since these areas were a centre of diversity of the *P. coccineus* complex which is very rich in forms. Many areas still remain to be explored, in view of material collected compared with the abundant herbarium material available. The complications involved in handling these forms *ex situ* mean that they need to be conserved *in situ*.

Cultivation practices

In most of its nuclear area, *P. coccineus* is sown

TABLE 3 **Selected cultivated species of *Phaseolus*: altitude, daytime temperature, mean annual precipitation, duration of growth cycle from start to end of harvest, yield potential in tropical areas**

Species	Altitude (*m*)	Temperature (*°C*)	Precipitation (*mm/year*)	Growth cycle (*days*)	Yield (*kg/ha*)
Phaseolus coccineus	1 400 - 2 800	12 - 22	400 - 2 600	90 - 365	400 - 4 000
Phaseolus acutifolius	50 - 1 900	20 - 32	200 - 400	60 - 110	400 - 2 000
Phaseolus lunatus	50 - 2 800	16 - 26	0 - 2 800	90 - 365	400 - 5 000
Phaseolus polyanthus	800 - 2 600	14 - 24	1 000 - 2 600	110 - 365	300 - 3 500
Phaseolus vulgaris	50 - 3 000	14 - 26	400 - 1 600	70 - 330	400 - 5 000

with maize and other varieties or species (*P. vulgaris, P. polyanthus*) following documented practices, since precipitations allow their association. In Durango and Zacatecas (Mexico), under heavy rain conditions it is sown alone, either in widely spaced rows or broadcast, depending on the type of ploughing. Manual harvesting is still common; the pods are gathered and left to dry in the sun before being beaten and the seeds are stored in sacks.

Estimation of the yield in cultivated fields is difficult, since farmers intercrop *P. coccineus* with other beans or harvest it periodically. It produces 400 to 1 000 kg per hectare in the shrubby forms while, for climbing varieties, the yield can be much higher (Table 3). In the United Kingdom, for crops with young pods, more than 23 tonnes per hectare have been recorded.

Prospects for improvement

The scarlet runner bean has been used on many occasions for improving the common bean but only in very few cases has its own improvement been addressed, although specialists agree on the hardiness of the species against several fungi, bacteria and viruses.

The delayed production of climbing forms may be considered a limitation. The number of shrubby forms is not sufficiently high (especially of those with white seeds) and several of them have a low yield. Not all colours and seed stocks exist in these varieties, and this is particularly the case with shrubby forms. Floral abscission can at times be considerable – perhaps because of the lack of pollinators – and causes yield losses.

Many cultivars root easily and can be maintained over several years thanks to their fleshy root. Their large attractive flowers make insect pollination easy (this crop may be assumed to have a positive effect on local entomofauna). A hybrid scarlet runner bean could be developed; however, unlike the kidney bean or the tepary bean, it is not known whether there would be a strong heterosis effect.

The use of the scarlet runner bean to complement maize in silage deserves investigation since, as well as its fodder value, the plant can limit soil erosion. It may also be useful interspersed in young forest or fruit plantations (to give soil protection, fertilizing value or additional income).

Because of its type of germination, *P. coccineus* is a useful species for fighting the bean fly (*Ophiomyia phaseoli*) in the highlands of East Africa.

Phaseolus acutifolius

Botanical name: *Phaseolus acutifolius* A. Gray

Family: Fabaceae

Common names. *English:* tepary bean; *Mayan:* xmayum (Mexico [Campeche]); *Spanish:* tépari, (name of Opatan origin) (Mexico [Sonora]), escomite or escumite (Mexico [Chiapas]), frijol piñuelero (name of hybrid origin) (Costa Rica)

This species has been grown for a long time in Mesoamerica, mainly as a vegetable in desert zones or areas with a long dry period. Unlike the case of other cultivated species of the genus, *P. acutifolius* was first described in its wild form while the relationship with the cultivated form was recognized later. Archaeological findings have shown that this species was grown in ancient times in the southeastern United States (where it apparently penetrated from Mexico 1 200 years ago) and Puebla (where it existed 5 000 years ago). Geographical distribution of the cultivated form extends from Arizona and New Mexico to Guanacaste, Costa Rica, on the dry subtropical slope of the Pacific. The distribution of *P. acutifolius* is sporadic, which is reflected in its market. The main product is a dry seed which is eaten because of its rich protein (17 to 27 percent) and carbohydrate content. It is also used as a young tender string bean and as fodder after harvesting.

It is still not known precisely where the species was domesticated. It should be noted that electrophoretic analyses of the phaseolin and isoenzymes indicate that the domesticated populations were few. Either because of its historic extinction, because the initial genetic base was already reduced at the time of its domestication or because of the autogamy of the species, the cultivated genetic potential does not seem to have been very extensive, to judge from its subsequent development. Following are some of the causes that several authors have reported as having led to neglect of the tepary bean:

- the availability of cheap water in desert areas which enables the cultivation of fodder plants or garden produce and other vegetables of greater value (kidney bean, cowpea), as the tepary bean's yield remains the same or even diminishes with irrigation;
- the loss of eating traditions in indigenous communities;
- the shortage of demand on the big markets.

Its cultivation potential in desert areas is extensive and is still to be explored.

Botanical description

P. acutifolius is a desert therophyte and is easily distinguished from other species of beans by its epigeal germination, sessile primary leaves, acute rhomboid folioles, pseudoracemes – with two to four fruit-bearing stems – small pink flowers (white in some cultivars) with very small triangular bracteoles and pods that have sutures marked with five to ten ovules. Autogamy appears to be dominant. Two wild forms are recognized: var. *acutifolius* with rhomboid folioles and var. *tenuifolius* with linear, sometimes sagittate, folioles. A third wild form appears sporadically with narrowly falcate folioles which, because they have different blastogenic characteristics from the var. *tenuifolius* and possess a certain incompatibility for crossing, could be considered a separate species (*P. parvifolius*).

The cultivated form, like the wild forms, has a short cycle, flowering 27 to 40 days after germination and ripening at 60 to 80 days. The plants wither completely (except *P. parvifolius*). In the wild forms, seeds are dispersed within a radius of 3 m by explosive dehiscence of the pods. In some cultivars there is a brief postharvest latency of one month. The seeds of the wild plants germinate through the imbibition caused by the heavy desert rainfalls of the following year. However, only in some is germination staggered over three years.

Ecology and phytogeography

The cultivated form is found from 50 m to 1 920 m above sea level. It requires an annual precipitation of 250 to 300 mm, although it is grown in Mexico in regions with a precipitation of 150 mm (Sonora) to 750 mm (Campeche). During the vegetative period, the daytime temperature can reach 20 to 32°C. It grows on well-drained, sandy, muddy, sometimes organic soils with pH 6.7 to 7.1.

There is an ecological specialization in the wild forms of the tepary bean: var. *acutifolius* of Arizona, New Mexico, Lower California, Sonora, Chihuahua, Durango, Sinaloa and Jalisco occupies semi-sunny habitats with the mesquite on the banks of streams, while var. *tenuifolius* colonizes the sunny slopes with cacti and thorny shrubs in Arizona, New Mexico, Lower California, Sonora, Chihuahua, Durango, Sinaloa, Nayarit, Jalisco, Querétaro, Michoacán, Guerrero, Oaxaca and Jalapa. The cultivated form is a heliophyte and has characteristics that allow it to tolerate excessive sun.

Genetic diversity

Compared with the kidney bean, there is less seed variability. Basically two forms occur: one with a fairly small, rounded, white or black seed; and another with a larger-sized angular, rhombohedric seed that may be white, greenish white, grey, bay, dark yellow, mahogany, black or purple-mottled or coffee in colour. The average weight of 100 cultivated tepary bean seeds is between 10 and 20 g and, for the wild form, between 2 and 5 g. Two cultivars have been cited: one is white (Redfield) and another is dark yellow. Both result from mass selection. Although the cultivated and wild materials do not have a definite habitat, a desert environment is necessary. Whereas the wild varieties are generally climbers with a few guide shoots (2 to 4 m in length), there are two cultivated groups: the indeterminate shrubby varieties with short guide leaves and the indeterminate creepers with long guide leaves, which climb if they find support. The author knows only one escape variety. The secondary genetic stock is not well known: the kidney bean may be considered to be within the tertiary stock.

A good number of cultivars from which collections have been made mainly in Mexico appear to be no longer sown. It seems unlikely that many more cultivated forms will be found but it would be useful to re-examine the southern area of distribution. This examination is an example of a germplasm collection programme that has enabled a good part of the crop's variability to be saved. The two wild forms represent the major source of variation for future improvement of the species. As some plant species are threatened by overgrazing, it would be advisable to collect germplasm from Nayarit to Jalapa.

Cultivation practices

In the southern area of its distribution, the rural communities have conserved *P. acutifolius*, particularly because of its early maturity and reduced cultivation requirements. It is sown on the edge of maize fields, at the start of the rains to obtain the green bean and at the end of the rains to obtain the seed, or on plots around houses in virtually any period. In the northern area of its distribution (southeastern United States, northeastern Mexico), it is sown under heavy rain conditions in small fields with a favourable topography or on the edges of streams, generally alone or with some gourds and tolerated weeds. After the first heavy downpour, the land is ploughed and then sown in rows or broadcast following the second downpour. The plants are pulled up when they reach maturity and are left to dry in the sun. One week later they are trodden on a clean surface while the seeds are collected and winnowed with a basket. The seeds used to be stored in baskets or clay vessels (nowadays in tins or plastic bags), thus maintaining their germinating capacity for three years. In Campeche, to store seed for sowing, packets are made with the unopened pods and placed in contact with the smoke of embers.

Yields are estimated to be 200 to 900 kg per hectare, with wide variations depending on sowing density and rainfall. About 1 000 to 2 000 kg per hectare are obtained with fertilizer, with harvests of up to 4 tonnes per hectare.

Prospects for improvement

The tepary bean is considered to be a useful species for improving the kidney bean (it is not attacked by mildew or smut, *Xanthomonas phaseoli*), but no programmes have been carried out for improving the tepary bean itself. Unlike many leguminous vegetables, it gives an acceptable yield with less than 400 mm of annual precipitation. Its small seed size could be corrected by improving the species; the variability in colours and seed standards could also be increased. A pronounced heterosis is noticed when lines are crossed and there is a possibility of hybrid tepary beans being produced (it would be necessary to determine whether the secondary stock would make it possible to increase the flower's attractability to insects[1]). Some populations are susceptible to rust, oidium, mildew, root rot, leafminers, bruchids and leafhoppers. Some lines have good or excellent levels of resistance to these pests and diseases. In cultivation, the germplasm has proved susceptible to high temperatures, acidity, aluminium toxicity and common mosaic diseases.

Its potential for introduction into desert areas (the American tropics, the Sahel, the Near East, India) is considerable but it has not been exploited. For example, in July 1985, the author sent a small sample of tepary bean plants to Chincha in Peru for evaluation; in 1989 one of the tepary beans was already being sold under the name of cuarenteno in Chiclayo. In many areas its use as a cover plant or as a crop merged with millet (*Pennisetum* sp.), prickly pear (*Opuntia* sp.), mesquite (*Prosopis* sp.) and jojoba (*Simmondsia* sp.), for human or animal consumption, has not been exploited either. It should be possible to use it as a postharvest crop when temperatures are still favourable and residual humidity is low. One of the main reasons for promoting cultivation of the tepary bean is to limit the use of water in subdesert areas.

Research should be orientated towards increasing the collection of germplasm; distributing seed from gene banks to farmers; divulging information through agricultural extension services on the cultivation potential of the tepary bean in dry zones; setting up seed improvement projects; developing food technologies suited to leguminous vegetables (for example, industrial processing of proteins), which would free the farmer from market requirements; and promoting information on the methods of consumption in order to re-upgrade the use of this legume.

Phaseolus lunatus

Botanical name: *Phaseolus lunatus* L.
Family: Fabaceae
Common names. English: butter bean, Lima bean, Burma bean, duffin bean, Rangoon bean

There are two main genetic stocks domesticated from two separate wild forms and with morphotypes from a different seed.

[1] No cytoplasmatic androsterility or agents re-establishing fertility have been recorded in *P. acutifolius*.

Common names of the small-seed cultivars (24 to 70 g per 100 seeds). *Mayan:* ib (Mexico [Yucatan]); patashete (Mexico [Chiapas]); ixtapacal (Guatemala [Suchitepéquez]); *Spanish:* sieva, comba (Colombia [Guerrero]), furuna (Mexico [Jalapa]), chilipuca (El Salvador), kedeba (Costa Rica), frijol caballero (Cuba), haba (Puerto Rico, Panama), carauta (Colombia [Atlantic]), frijol de año (Colombia [Tolima]), guaracaro (Venezuela); *French:* pois souche (Haiti)

The Caribbean group is made up of small, round seed material distributed in that area.

Common names of the large-seed cultivars (54 to 280 g per 100 seeds). *Spanish:* lima (because of its origin from the coast of Peru), torta (Colombia [Nariño, Huila], Ecuador [Imbabura, Azuay, Loja]), layo (Peru [Cajamarca]), pallar (Peru [Lambayeque, La Libertad, Lima, Ica, parts of the range]), palato (Bolivia [Chuquisaca]), poroto manteca (Argentina)

Archaeological findings in Ancash, Peru, indicate that, after *Lagenaria siceraria*, the large-seed species were among the first to be cultivated (8 000 years ago), while the small-seed materials in Mesoamerica date back only 1 200 years. The large-seed material appeared 5 000 years ago on the coast of Peru, where they were of great nutritional and cultural value, particularly for the Mochican and Nazca peoples. Distribution of the wild form on the northern range (electrophoresis test results show that it is the ancestor of the Andean stock) suggests that domestication took place in this area and that it expanded towards the high parts of Ecuador and Colombia as well as towards the Peruvian coast and other high parts of Peru and Bolivia. Nowadays, the green seed in particular is eaten. On the Peruvian coast, dulce de pallar, a kind of Lima bean conserve, is prepared from the dry seed. The aesthetic value of the seeds has enabled them to be used in recreation activities in peasant communities. The small-seed cultivars were domesticated from a wild form, possibly in Mesoamerica and in more recent times. The seeds are eaten dry (the Mayans of today prefer them refried) or green. In Asia the young plants or young leaves are consumed; in Madagascar they are used to prepare hay.

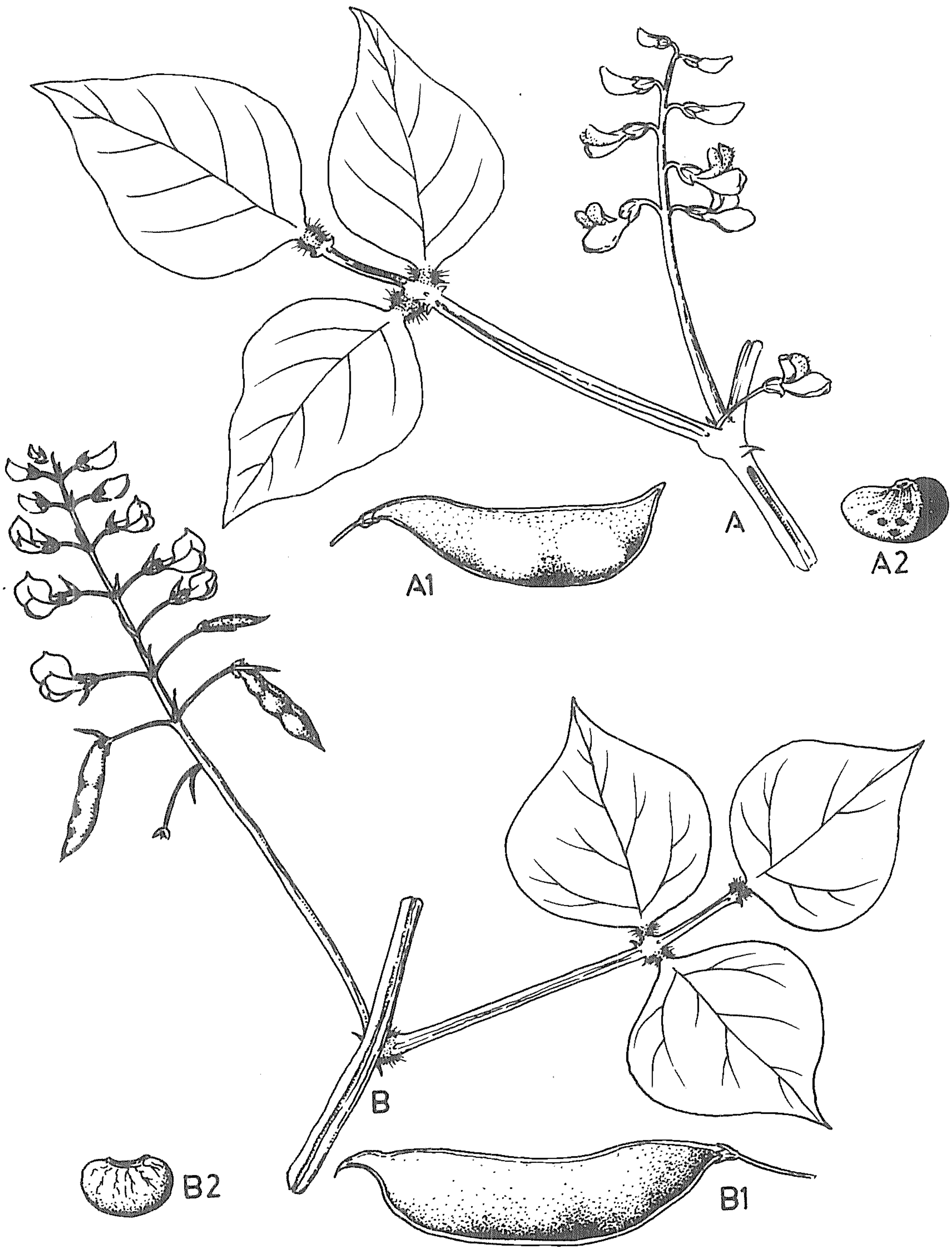
Among the reasons for the present marginalization of *P. lunatus*, apart from abandonment of the traditional diet with the rural exodus and changes in peasant customs, we should mention the presence of a cyanogenic glucoside which in some cultivars, if detoxification is omitted, may cause poisoning. Standardization in the consumption of leguminous vegetables (some varieties of common bean or cowpea) has been prejudicial to the Lima bean because of the presence of this glucoside. The small-seed cultivars, particularly under irrigation, suffer from the competition of soybean (and sometimes the cowpea because of its price). In the Peruvian Andes, Lima beans have heavy competition from the introduced lablab [*Lablab purpureus* (L.) Sweet] which is resistant to weevils, and the introduced pigeon pea [*Cajanus cajan* (L.) Mills], which is more tolerant of drought.

Botanical description

P. lunatus is a pluriannual species (except for a few modern cultivars) with epigeal germination and fibrous roots. Its ancestral forms come from low- or medium-altitude tropical deciduous forests. It is easily distinguished by its half-moon seeds (with the exception of a group of cultivars from the Caribbean that has a spherical seed). It is striated from the hilum and has: deltoid folioles; pseudoracemes with four to 12 fruit-bearing stems; small flowers, with a standard which

FIGURE 4

Beans: A) *Phaseolus lunatus*; A1) legume; A2) seed; B) *P. polyanthus*; B1) legume; B2) seed



is greenish (Mesoamerica) or purple (Andes); very small, roundish bracteoles; and smooth, falcate pods with three to six ovules. The two wild forms display marked differences but do not justify differentiated taxonomic treatment because of the considerable introgression among their genetic stocks. It is an autogamous species with an introrse stigma, but cross-pollination may exceed 32 percent.

The earliest genotypes flower 35 days after sowing and complete their cycle in around 100 days. Others may have two flowering cycles per year depending on the distribution of rainfall. In dry areas, the plants sprout from the lower part of the stem with the return of rainfall. In the majority of the traditional varieties, the guide leaves are long (3 to 6 m), indeterminate, creeping (and therefore useful as ground cover) or climbing.

The fibrous roots may attain several metres on filtering soils with deep humidity (Yucatán, coastal Peru), thus giving the plants great vegetative vigour (greater than maize) and a survival period of up to four years. In the wild populations, the seeds are dispersed through explosive dehiscence of the pods.

Ecology and phytogeography

Although not strict, there is a certain distribution pattern of the forms. The small-seed wild form is found from Sinaloa in Mexico to Salta in Argentina, generally below 1 600 m. The small-seed cultivars frequently grow at a lower altitude in the Pacific area of Mesoamerica, from Arizona in the United States to Chocó on the western range of Colombia as well as the Ecuadoran coast, and from Yucatán and Colombia to Venezuela and in the Antilles. It also exists in northeastern Brazil and in Formosa, Argentina. The larger wild form is distributed in Ecuador and in the north of Peru between 320 and 2 030 m. The large-seed cultivars are distributed in Peru from 50 to 2 750 m and in the high valleys of Chuquisaca and Cochabamba in Bolivia. Curiously, some also exist in the south of Brazil.

P. lunatus is a generally hardy species which prefers dry climates and deep soils (pH 6 to 7.2) with good drainage. Although it is true that some forms tolerate the climate of the lower tropics well, the species' exceptional altitude range should be mentioned, particularly in Peru where some forms withstand low temperatures (Table 3). *P. lunatus*, both cultivated and wild, is rather heliophytic.

Genetic diversity

The intraspecific variability of *P. lunatus* is particularly high in the groups of Siva and Gran Lima varieties and less in the Caribbean group. There are several commercial cultivars, particularly in California (for example, Henderson and Fordhook) and for domestic consumption (unripe green seeds in salads) in the United States. Relatives of the Andean wild form are *P. augusti* Harms, *P. bolivianus* Piper and *P. pachyrhiozoides* Harms. Of the cultivated species, the latter has the widest secondary stock.

There are numerous gene banks, mainly in Pullman in the United States (USDA), Chapingo in Mexico (INIFAP) and Palmira in Colombia (CIAT). Germplasm has been collected in order to save traditional material cultivated in several regions of the American tropics where varieties have rapidly disappeared. It could still be collected profitably in some parts of the Yucatán peninsula, northern Colombia, San Martín in Peru and in Paraguay.

In the case of wild material (particularly of the small-seed form) many regions fall short for collecting specimens: Tamaulipas, Sinaloa, Michoacán, Oaxaca, Chiapas, Petén in Mexico, El Salvador, Nicaragua, Panama, Venezuela and eastern Bolivia.

Cultivation practices

In the neotropical zones of America, it is very common to find from one to five *P. lunatus* plants in household vegetable gardens and on small plots, as it is customary for families to add a few green seeds to soups. In the Mayan Yucatán, this bean is traditionally sown as part of the slash-and-burn clearing system with maize, buul (*P. vulgaris*) and gourds. On the coast of Colombia, carauta is found on plots with maize, cassava and guandul. On the coast of Peru, it was frequently found broadcast on the banks of mountain streams where it absorbed the floodwaters. Similar practices may have existed in the *cinteño* valley in Bolivia before the introduction of the grapevine. Nowadays, in Chinca, Peru, it is sown as a commercial monoculture (white seeds) on ridges with irrigation. In many parts of the Andean range (in the dry inter-Andean valleys at 2 000 m of Nariño, Colombia; Imbabura and Azuay in Ecuador; and Cajamarca in Peru) *P. lunatus* is frequently seen growing on old walls separating plots and roads or on landslides and slopes. The peasants thus use the spaces of least value. In other parts of Peru (Cajamarca, La Libertad), the Gran Lima types are sown around the edge of small farms. In some places, the plants behave spontaneously and cross with the wild forms that exist in the surrounding area (for example in Succhubamba, Cajamarca).

As it is sown almost individually in many family vegetable gardens, it is difficult to give figures for yield per area. Furthermore, periodic harvesting complicates the evaluation. In the shrubby forms, seed yields of 2 000 kg per hectare have been recorded and, in climbing varieties, more than 3 000 kg per hectare.

Prospects for improvement

Within the cultivated species, *P. lunatus* competes with *P. coccineus* through the genetic stock which is wider (primary and secondary) and differentiated into a very early form (for which there is genetic progress); it has a good rate of allogamy and heterosis has been found; consequently there are good prospects for improvement. *P. lunatus*' relatively late production, as well as that of the indeterminate creeping forms, may be compensated by exploiting the earlier shrubby forms. There is a wide variation in the glucoside content in the seed, and potential for improvement with types of less than 5 ppm, without any correlation with the colour of the tegument. The evaluation of cultivars to determine the glucoside content will make it possible to establish many materials in traditional areas of cultivation and consumption. Its hardiness and lengthy production may be advantages in adverse conditions where other leguminous vegetables do not prosper. The aesthetic value of the Gran Lima varieties may be considered in the development of handicrafts (which could be useful in remote parts of the Andes). The restoration of traditional dishes and uses (for example in recreation) would also contribute to the crop's promotion. The selection of varieties resistant to grub (*Acanthoscelides* sp.) and weevil (*Apion* sp.), particularly the Gran Lima, and of shrubby forms with a greater diversity of seeds (colour, shape) as well as the study of production techniques (the use of nettings, sowing on slopes, etc.) should be mentioned as research priorities.

Phaseolus polyanthus

Botanical name: *Phaseolus polyanthus* Greenman

Family: Fabaceae

Common names. *Spanish:* botil (Mexico [Chiapas]), piloya (Guatemala [Chimaltenango]), dzich (Guatemala [San Marcos]), piligüe (Guatemala [Alta Verapaz]), petaco (Colombia [Antioquía and western region]), cacha (Colombia [Cauca, Huila and southern region]), matatropa (Colombia [Huila]), toda la vida (Ecuador, northern region of Peru).

The taxon *P. polyanthus* was recently acknowledged as a result of identification of its ancestral forms. There are no recordings of this legume on archaeological sites, in spite of the fact that the seeds found have been analysed thoroughly. The ecological conditions under which this species grows may not have been favourable for its preservation. Mention has been made of how old this crop must be in Mexico. In comparison with the wild forms and the other species, *P. polyanthus* is less evolved, which appears to be the result of its more recent domestication.

It has frequently been cultivated together with maize, gourds and two species of bean (*P. coccineus* and *P. vulgaris*) in Mesoamerican regions with a humid climate and at an intermediate altitude. Like the scarlet runner bean, this crop has been reduced with modification of the traditional maize field system in many parts of Mesoamerica. If peasants have to cease cultivating a species of bean, they keep the kidney bean, which generally obtains the best price. Among the other causes of its marginalization is the extension of coffee plantations and livestock rearing in its area of cultivation. As their incomes increased, peasants tended to abandon consumption of this legume. Traditionally, the green seed is preferred (either because it is easier to digest or because of its softer tegument) when the pod reaches physiological maturity and the dry seed is favoured less; it is eaten in soups, stews or even as a sweet (Amazon region).

Botanical description

Only pluriannual forms of *P. polyanthus* are known, which can live from two to four years. In drier parts (for example, western Cajamarca, Peru) it tends to behave as an annual. It is easily distinguished from the other species by its epigeal germination; fibrous, fasciculate roots; inflorescences with six to 16 fruit-bearing stems; primary bracts and long, narrow bracteoles (giving the pseudoraceme the appearance of a spike); white or lilac flowers (purplish pink in the wild form); and terminal stigma. Its seed (70 to 100 g per 100 seeds for cultivated varieties and 16 to 25 g for wild forms) has a wide, elliptical hilum and the parahilum is frequently broken.

Ecology and phytogeography

P. polyanthus is distributed in intermediate altitudes (800 to 2 600 m) in cool, damp climates with one dry period per year (Table 3); it has a long flowering period (two to five months) and can have two flowering and fruit-bearing periods per year if the rainy season is heavy (Colombia, Venezuela). It prefers deep, organic, damp and well-drained soils with pH 6.2 to 6.5 and it tolerates a degree of shade.

The cultivated form is found in Puebla, Veracruz, Oaxaca and Chiapas (Mexico). In Guatemala, it can be seen in Huehuetenango, San Marcos, Quezaltenango, Totonicapán, Baja and Alta Verapaz, Sololá, Chimaltenango and Sacatepéquez. It is also distributed in the upper parts of the Caribbean (Jamaica, Dominican Republic) and Costa Rica. It is cultivated in South America, where it is found in secondary vegetation, including wooded vegetation, from Mérida in Venezuela to Apurimac in Peru and in the western and central ranges of Colombia (the *petaqueras* of Antioquía), Ecuador (Azuay, Pichincha, Tungurahua) and northern Peru (Cajamarca, Amazon, Junín). To date, the wild form has been found only in the central-western part of Guatemala, where it is a liana that grows in the low, humid mountain forest; the possibility of it also occurring in the mountainous zone of the Jalisco-Michoacán boundary in Mexico should not be excluded.

Genetic diversity

This species is considered to be the least evolved of the cultivated *Phaseolus* species, hence it should have a greater potential for future development. There is little phenotypic variation (only the indeterminate climbing growth habit), including in the seeds. Normally it has orangy yellow seeds, but other colours do appear: reddish brown, bay, black and creamy white, for example. Seeds of the latter colour were found by the author in the Amazon region of Colombia and in Loja, Ecuador. It may have potential as a commercial crop in northern Peru and may compete as a plant with the caballeros (*P. vulgaris* with a large, round white seed), which do not produce in humid areas. Greater variation is seen in the seed where natural hybrids exist with *P. coccineus* (for example, in Putumayo, Colombia) and with *P. vulgaris* (for example in Tolima, Colombia) where colours may be combined with purple, coffee, etc. To date, there do not seem to be any properly recorded cultivars.

It is evident that *P. coccineus*, *P. polyanthus* and *P. vulgaris* are genetically close as a result of natural introgression among the species. However, each comes from a different and individualized ancestral form. The reason for this relationship should be found in the origin of the ancestral forms. Other species of the *P. coccineus* complex may also be considered to be close to the cacha; the genetic stock of *P. polyanthus* is therefore wide.

An exact evaluation of genetic erosion in this species is difficult: in some parts of Guatemala (San Marcos, Chimaltenango) and Costa Rica, where the traditional maize field cultivation system has been modified, certain genotypes are disappearing; in others (Cauca, Tolima, Amazon region, in Colombia and Junín in Peru) it appears to extend into ruderal vegetations because peasants throw seed on roadsides and in smallholdings, etc. One farmer in Huila, Colombia, mentioned that it was the first seed that he sowed in the slash-and-burn system of Los Páez. The species' hardiness in humid environments provides food when the maize harvest is insufficient and explains its frequent presence in secondary forests in Colombia, Ecuador and northern Peru. It is even more difficult to evaluate erosion, as it is a predominantly allogamous species (although the local variation of this allogamy is not well known). However, it does seem useful to document the evolution of the native material in its areas of genetic cultivation in Mexico and Guatemala and to collect germplasm in appropriate cases. In the southern area of its distribution, where there seems to be less variation and erosion, collection would not seem to be urgent. The situation is different in the case of the wild ancestral form: its distribution area in central-western Guatemala is threatened by urbanization and agriculture (the primary forest where it grows is being cut down to set up coffee plantations). It is urgent to complete collection of germplasm and to ensure that at least some plant species are included in *in situ* conservation within the perimeter of natural parks. This method should also be considered for the few sites where there is natural introgression.

There are collections of this species, mainly in Chapingo in Mexico (INIFAP); Chimaltenango in Guatemala (ICTA); La Molina in Peru (INIAA); and Pullman in the United States (USDA). The widest collection is that of the CIAT in Palmira, Colombia.

Cultivation practices

The majority of the cultivation practices mentioned for the tepary bean in the high humid zones of Central America also apply to the cacha bean. Although it is sown mixed with tepary beans, it frequently ripens a little earlier; separate harvesting (especially to eat it when green) is possible but is not always practised. In the

Andes it is frequent to see it in enclosures or in family vegetable gardens where it grows without any special care.

Prospects for improvement

A limiting factor appears to be the lesser digestibility of *P. lunatus* which has been verified in certain areas (Amazon region). The documentation of current consumption practices in peasant communities must be considered a priority before embarking on an investigation of its nutritional quality. It should be borne in mind that until the very recent past these beans were eaten several times a week. The lack of variation in seed colour is a problem which could be corrected partly with the distribution of germplasm from collections and through additional gatherings, particularly where there is introgression with *P. coccineus* and *P. vulgaris*. Variation in colour, type of seed and growth habits could be obtained through cross-breeding programmes that explore the primary and secondary genetic stock of *P. polyanthus*. Evaluation is still very much in its initial stage and is a priority for agrarian research. It would be very useful, since it is known that this species offers characteristics of resistance to several pests and diseases such as *Ascochyta* sp. (in the cool, humid parts of the Andes) and *Ophiomyia phaseoli* (in East Africa), respectively. There are genotypes ready for delivery to the farmer, particularly in conditions that are adverse to the kidney bean. The consumption of *P. lunatus* as a green seed could be recommended and recipes developed to improve preservation of the green seed. Its cultivation could also be encouraged in family vegetable gardens. Since the plant is attractive to livestock, it could be considered as a fodder crop in association with maize. In agrosilvicultural contexts (for instance in young plantations or hedges against erosion), it is possibly the best bean species to use. Its role in coffee plantations could also be considered from the point of view of fertilizing value and soil protection.

Conclusion

The bean was domesticated at a time when the current knowledge of molecular genetics and nutritional science was obviously not available to ensure selection of the material with the best evolutionary and nutritional potential. In addition to the kidney bean, four other species have been domesticated and have been maintained for thousands of years. It is not known whether the initial success of the kidney bean was due to its greater evolutionary potential compared with the other species or whether particular circumstances caused its domestication. Nor are all the reasons known for its promotion throughout the 200 years after 1492. Consequently, the germplasm collected of those species during the last 60 years, and the information relating to them, are possibly scarce in relation to what must have existed before the conquest. However, what has been able to be recovered is surprising and offers promise. In spite of all the changes that have occurred with the kidney bean since the fifteenth century, it has been difficult to modify its ecology drastically and the alterations that the latter may have suffered have had negative effects on species yield. Ought we not now give the neglected beans an opportunity?

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Cucurbits (*Cucurbita* spp.)

One plant group with the most species used as human food is the Cucurbitaceae family. Within this family, the genus *Cucurbita* stands out as one of the most important. Five of its species – *Cucurbita argyrosperma* Huber, *C. ficifolia* Bouché, *C. moschata* (Duchesne ex Lam.) Duchesne ex Poiret, *C. maxima* Duchesne ex Poiret, and *C. pepo* L. – have been domesticated in the New World and for thousands of years they have been cultivated or at least handled by American societies.

In spite of the current marginalization of some of these species, from very remote times all have contributed essential food products to the diet of rural and some urban communities on the American continent and in many other parts of the world. With the exception of *C. maxima*, whose centre of origin is in South America, it is assumed that the other four cultivated species were domesticated in Mesoamerica, although this has not been confirmed in all cases.

During the second half of the 1980s, a great quantity of information was collected on the origin and evolution of the four species. The taxonomic and genetic limits of *Cucurbita argyrosperma* and *C. pepo* have been redefined and their closest-related wild species have been classified into intraspecific categories within these limits. The results of this research have raised some doubts about the Mesoamerican origin of *C. ficifolia* and *C. moschata*, suggested so often in many publications.

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Cucurbita argyrosperma

Botanical name: *Cucurbita argyrosperma* Huber

Family: Cucurbitaceae

Common names. *English:* cushaw (United States); *Spanish:* calabaza, calabaza pinta, calabaza pipiana (Mexico), pipián (Mexico, El Salvador, Nicaragua, Costa Rica), saquil, pipitoria (Guatemala)

Origin, domestication and expansion

Cucurbita argyrosperma is one of the cultivated species of the genus which has undergone the most profound study in recent years. There are two subspecies:

i) argyrosperma, comprising four varieties – *argyrosperma*, *callicarpa*, *stenosperma* and *palmieri* – three of which include all the cultivated types, while the fourth corresponds to spontaneous populations of northeastern Mexico that are generally known as *Cucurbita palmieri* L. Bailey;

ii) sororia, which includes wild populations with a wide distribution from Mexico to Nicaragua, originally described under the name *C. sororia* L. Bailey. This subspecies has been designated as the wild ancestor of the group.

According to the age of the archaeological remains discovered thus far, it has been suggested that domestication of *C. argyrosperma* must have occurred in southern Mexico more than 7 000 years ago.

The characteristics that were most transformed in the process of domestication of the ssp. *argyrosperma* were, as in other crops, mainly those connected with handling and preferred uses. For example, relatively uniform germination; a reduction in size and abundance of trichomes; an increase in the size of parts and organs used, such as fruits and seeds; and a reduction in the bitter taste of the flesh. It is considered that var. *argyrosperma* is the least specialized or most primitive of the group and that var. *callicarpa*, on the other hand, is the most recent or specialized.

The different degrees of variation in the nutritionally important parts of the three cultivated varieties of the complex *argyrosperma* suggest a strong association with human interests. The relatively large seed size of the var. *argyrosperma* indicates that it was mainly selected to obtain seeds, while the great diversity of shapes, colours and size of the fruits and seeds of var. *stenosperma* and *callicarpa* indicate that selection had a double aim: to obtain flesh as well as seeds.

Unlike with the rest of the cultivated species of *Cucurbita*, data on the distribution of cultivated *Cucurbita argyrosperma* varieties outside America are very scarce and there is no certainty that this species was cultivated at any time in the Old World or even outside its general area of domestication.

In South America, it is grown in Peru and Argentina, although it appears to involve very recent introductions of certain cultivars which can be classified within the var. *callicarpa*. In the United States, some cultivars of var. *callicarpa* are cultivated on a very low scale for nutritional purposes, and one cultivar of var. *argyrosperma*, Silver Seed Gourd, is occasionally grown as a horticultural curiosity.

The reasons for the sparse world distribution of this species are not known; although the situation is not surprising, given the low quality of the fruit's flesh compared with that of *C. moschata* or *C. pepo* and the size of the seeds of all the cultivated varieties that may have been attractive to the first Europeans who learned of them.

Uses and nutritional value

Throughout its distribution area, the flowers, young stems, young fruit and ripe fruit of *C. argyrosperma* are eaten as vegetables. The ripe fruit is occasionally used to prepare sweets although it is used most frequently as feed for livestock and poultry. The seeds are eaten whole, roasted, toasted or ground and are the main ingredient of sauces used to prepare various stews (for example, *pipián* – meat cooked in thick chili sauce, *mole verde* – a stew prepared with chili and green tomatoes). The seeds are the most important product, chiefly because of their oil (39 percent) and protein content (44 percent), and their consumption in urban areas of Mexico and other countries of Central America is fairly common.

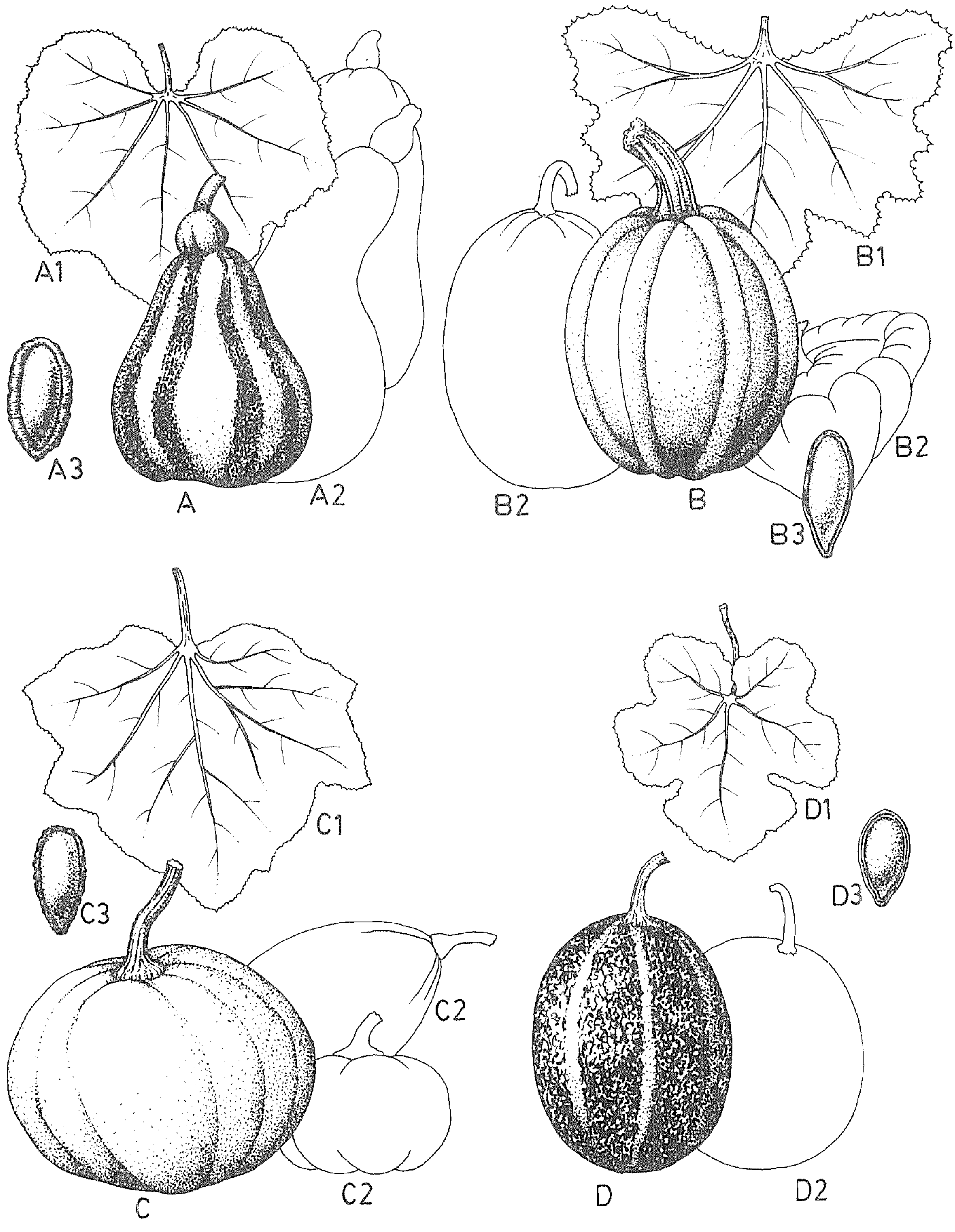
In some regions of Mexico, the seeds and also the unripe fruit of wild taxa are used as food. The latter are eaten after being washed and boiled several times to rid them of the bitter taste deriving from the cucurbitins present in the flesh and placentae, while the seeds are simply washed, seasoned with salt and roasted or toasted. On the Yucatán peninsula, peasants use the flesh of the cultivated varieties' fruit to treat burns, sores and skin eruptions, while the seeds are prepared with water and used as an anaesthetic and to stimulate women's milk production for breastfeeding.

Botanical description

C. argyrosperma is a creeping or climbing monoecious plant, ranging from villous to pubescent and which may be hirsute, with short, rigid

FIGURE 5

Mesoamerican cucurbits: A) *Cucurbita argyrosperma*; A1) leaf; A2) fruit; A3) seed; B) *C. pepo*; B1) leaf; B2) fruit; B3) seed; C) *C. moschata*; C1) leaf; C2) fruit; C3) seed; D) *C. ficifolia*; D1) leaf; D2) fruit; D3) seed



and rather enlarged and sharp trichomes. It has fibrous roots and slightly angular stems. Its ovate-cordate leaves have petioles of up to 30 cm and measure 10 to 30 × 15 to 40 cm. They have white spots, number three to five and are lobulate with triangular or elliptical lobules. The margins are denticulate to serrate-denticulate. There are two to four ramified tendrils and pentamerous, solitary, axillary flowers. The male flowers are on pedicels of 10 to 20 cm and have a campanulate calyx of 5 to 20 × 8 to 25 mm. Their sepals are linear-lanceolate or (rarely) foliaceous and are 10 to 35 mm long. They have a tubular-campanulate corolla that is yellow to orange, 6 to 12 cm long, with five lobules for up to one-third of its total length and they have three stamens. The female flowers grow on sturdy peduncles of 2 to 3.5 cm; have a globose, ovoid-elliptical, botuliform or piriform, multilocular ovary, a small calyx and a corolla that is somewhat bigger than that of the male flowers. They have three stigmas. The fruit is short or long and piriform, straight or curved in the thinnest part and 11 to 50 cm long. It has a hard rind which is smooth to slightly ribbed, and is white with longitudinal green reticulate stripes or completely white. The flesh is white, yellow or orange, the seeds elliptical and slightly inflated, measuring 15 to 30 × 8 to 16 mm, with a white, smooth and even testa.

Ecology and phytogeography

The three cultivated varieties of *C. argyrosperma* are found in a relatively wide range of altitudes (0 to 1 800 m), generally in areas with a hot, fairly dry climate or a well-defined rainy season. The species does not tolerate very low temperatures, which limits its cultivation to the altitudes mentioned. Each cultivated variety has a fairly defined distribution model, although there are some areas where two varieties can be found cultivated simultaneously.

In Mexico, the var. *argyrosperma* is grown on the slope of the gulf (Tamaulipas, San Luis Potosí, Puebla, Veracruz, Tabasco, Chiapas and Yucatán). In Central America it has been recorded in Belize, Guatemala, Honduras, El Salvador, Nicaragua, Costa Rica and Panama. The var. *callicarpa* is found mainly on the Pacific slope, from the southeastern United States to central Mexico (Sonora, Sinaloa, Chihuahua, Zacatecas, Guanajuato, Nayarit and Jalisco). The var. *stenosperma* is endemic to Mexico and is grown in the central and southeastern states (Guerrero, Morelos, Michoacán and Oaxaca) as well as in some areas of the gulf slope (Veracruz and Yucatán).

Genetic diversity

Limits of genetic stock. Knowledge of the genetic relations of *C. argyrosperma* Huber and the consequent inclusion and definition of wild and cultivated taxa within its taxonomic limits have considerably widened the species' genetic stock. This includes: the local races of the cultivated varieties in the southeastern United States, Mexico and Central America; the two wild taxa of the complex (var. *palmieri* and ssp. *sororia*); and, in the United States, Green Striped Cushaw, White Cushaw, Magdalena Striped, Papago, Silver Seed Gourd, Japanese Pie, Hopi, Taos, Parral Cushaw and Veracruz Pepita.

Hybridization experiments of the taxa belonging to *C. argyrosperma* with other wild and cultivated taxa of the genus and some field observations have revealed that, with the cultivated species, *C. moschata* has the highest degree of compatibility. A second level of compatibility consists of the wild and cultivated taxa of *C. pepo*, some cultivars of *C. maxima* and the wild perennial species of *C. foetidissima* H.B.K. A third group is formed by *C. lundelliana* L. Bailey, and *C. martinezii* L. Bailey, with which crossings only produced fruit without viable seeds. The fourth and last group includes the perennial species *C. pedatifolia* L. Bailey, *C. digitata* A. Gray, in the broad sense and *C. radicans* Naudin, with which only a few fruits were able to be obtained but generally without viable seeds.

The wild species that have shown some degree of compatibility with the taxa of the complex *C. argyrosperma* possess genes resistant to some viral diseases that have a high incidence in the cultivated species.

However, because of two factors relating to interspecific crossings, some obstacles will have to be overcome before a successful plant improvement programme including all the taxa is carried out:

- hybrids with viable seeds were not always produced;
- when some success was achieved, the plant receiving the pollen was always from the complex *C. argyrosperma* and, in the case of the species of the last two groups, it always involved var. *palmieri* or ssp. *sororia*.

Germplasm collections. Germplasm collections are not so scarce for the cultivated taxa but they are in very short supply in the case of the wild ones. Most of the accessions come from Mexico and are deposited in the CIFAP's gene bank in Mexico and in the USDA's in the United States.

Cultivation practices

The cultivated varieties of *Cucurbita argyrosperma* are worked in the traditional heavy rain agricultural systems and are sown at the start of the rainy period (May-June). Development of these varieties lasts five to seven months; the young fruit for vegetables is harvested approximately three months after being sown, while the ripe fruit for seed is harvested between October and December.

In the Mixe region of the state of Oaxaca, var. *stenosperma* is also grown in the dry season on so-called humid ground. This practice is also recorded in some parts of the state of Sonora in northeastern Mexico, where some cultivars of var. *callicarpa* can be grown in the dry season, but always with the help of irrigation to ensure production throughout the year.

The only form of propagation is the sowing of seed which is done along with some of the traditional crops of this agricultural model (maize, beans and other species of *Cucurbita*). In some regions of Yucatán, Quintana Roo and Oaxaca the seeds of *C. argyrosperma* are often the first to be planted in the maize fields. Sowing begins shortly before the start of the rain and before the other associated crops are sown.

In some localities of Yucatán, sowing is done very quickly the day after the traditional burning of the stubble of the previous crop and long before the first rain and the sowing of other associated crops. The aim is to prevent the development of weeds which would affect production of the other species cultivated in the maize field, utilizing the rapidity of growth and cover attained by this species. Practices of this type show that the seeds of *C. argyrosperma* are completely suited to these regions and germinate even in conditions of low humidity.

Unlike other cultivated species of the genus, it is less frequent for varieties of the *argyrosperma* complex to be found in vegetable gardens or plots or in small agricultural holdings or to be associated with other species.

Cucurbita pepo

Botanical name: *Cucurbita pepo* L.
Family: Cucurbitaceae
Common names. *English:* pumpkin, vegetable marrow, summer pumpkin, autumn pumpkin; *Spanish:* calabaza (Mexico), hüicoy (Guatemala)

Origin, domestication and expansion

According to archaeological recordings, *C. pepo* appears to be one of the first domesticated species. The oldest remains have been found in Mexico, in the Oaxaca valley (8750 BC to AD 700) and in the caves of Ocampo, Tamaulipas (7000 to 500 BC). Its presence in the United States also dates back a long time, as the recordings in Missouri (4000 BC) and Mississippi (1400 BC) indicate. This species may have been domesticated at least on two occasions and in two different regions: in Mexico and in the eastern United States, in each case having *C. fraterna* and *C. texana*, respectively, as possible progenitors.

Eight groups of edible cultivars of *C. pepo* are known:

- **Pumpkin** (*C. pepo* L. var. *pepo* L. Bailey,) includes cultivars of creeping plants which produce spherical, oval or oblate fruit that is rounded or flat at the ends. The fruit of this group is grown to be eaten when ripe and sometimes is used as fodder.
- **Scallop** (*C. pepo* L. var. *clypeata* Alefield) has a semi-shrubby habit, the fruit ranges from flat to almost discoidal, with undulations or equatorial margins, and it is eaten before maturity.
- **Acorn** (*C. pepo* L. var. *turbinata* Paris) is both a shrubby and creeping plant with fruit which is obovoid or conical, pointed at the apex and longitudinally costate-grooved. The rind is soft, hence the fruit can be eaten in the ripe state.
- **Crookneck** (*C. pepo* L. var. *torticollia* Alefield) is a shrubby type, with yellow, golden or white fruit which is claviform and curved at the distal or apical end and generally has a verrucose rind. It is eaten unripe since the rind and the flesh harden when ripe.
- **Straightneck** (*C. pepo* L. var. *recticollis* Paris) is a shrubby plant with yellow or golden fruit and a verrucose rind similar to that of var *torticollia*..
- **Vegetable marrow** (*C. pepo* L. var. *fastigata* Paris) has creeper characteristics as a semi-shrub and has short cylindrical fruit that is slightly broader at the apex, with a smooth rind which hardens and thickens on ripening and which varies in colour from cream to dark green.
- **Cocozzelle** (*C. pepo* L. var. *longa* Paris) has cylindrical, long fruit that is slender and slightly bulbous at the apex; it is eaten in the unripe state and one of the most common names is Cocozzelle.
- **Zucchini** (*C. pepo* L. var. *cylindrica* Paris) is the most common group of cultivars at present. Like the previous group, the zucchini group has a strong affinity with the vegetable marrow and its origin is also recent (nineteenth century). Its plants are generally semi-shrubby and its cylindrical fruit does not broaden or else broadens only slightly. It is eaten as a vegetable in the unripe state.

With regard to traditional cultivars, it is common to see a fair representation of cultivars with characteristics similar to those of each of the commercial groups in one single field cultivated by Mesoamerican peasants. The question of the origin of the cultivars native to the Mayan area in the middle and low areas of Chiapas and the Yucatán peninsula still has to be resolved. These cultivars, whose fruits are either without or with unpronounced ribs and have rather rounded and oval seeds, are grown from a little above sea level to nearly 1 800 m.

The distribution of *C. pepo* outside America is possibly the best documented of this genus: it is known that some cultivars reached Europe approximately half a century after 1492 and it is even said that others originated on that continent. In contrast to *C. pepo*'s long-established presence in the Old World, it seems that its arrival in

South America was very recent. At present, the fruit of some cultivars (for example, Zucchini and Cocozzelle) has a nutritional and commercial role in several regions of the world.

Uses and nutritional value

Like the other cultivated species of the genus, the mature or young fruit and the seeds of *C. pepo*, as well as to a lesser extent the flowers and young tips of the stems, are eaten in many parts of its native distribution area and in other regions of the world. *C. pepo*'s nutrient content is similar to that described for the other cultivated species.

Botanical description

C. pepo has: creeping plants which are compact or semi-shrubby, annual, monoecious and pubescent-scabrous; broadly ovate-cordate to triangular-cordate leaves, 20 to 30 × 20 to 35 cm, with or without white spots, often with three to five deep lobules, and with denticulate to serrate-denticulate margins. Tendrils have two to six branchlets, or are simple and little developed tendrils in the semi-shrubby types. It has pentamerous, solitary, axillary flowers, the males of which have pedicels 7 to 20 cm in length, a campanulate calyx of 9 to 12 mm, linear sepals of 12 to 25 × 1 to 2 mm, a tubular/campanulate corolla, 5 to 10 cm long, which is divided into five for up to one-third or more of its length; and three stamens. The female flowers have sturdy, sulcated pedicels of 2 to 5 cm; the ovary is globose, oblate, ovoid, cylindrical, rarely piriform, smooth, ribbed or verrucose and multilocular; and the calyx is very small. The fruit is very variable in size and shape: smooth to heavily ribbed, often verrucose and rarely smooth, with a rigid skin varying in colour from light to dark green, plain to minutely speckled with cream or green contrasting with yellow, orange or two-coloured. The flesh is cream to yellowish or pale orange; it ranges from soft and not bitter to fibrous and bitter, has numerous seeds which are narrowly or broadly elliptical or rarely orbicular, slightly flattened and 3 to 20 × 4 to 12 mm.

Ecology and phytogeography

Traditionally, *C. pepo* is cultivated from North America to Central America and in some parts of South America, although it is generally said to be a crop of high areas. Like *C. moschata*, this species covers a fairly wide range of altitudes. In Mexico, there are native varieties which grow from very close to sea level and in semi-dry climates, such as the variety called tsol in Yucatán, to others which are cultivated at altitudes greater than 2 000 m, such as those called güiches in Oaxaca. In Guatemala, the native cultivars, commonly called güicoy, are grown above 1 000 m, while tsols are sown in the low, hot humid parts of the Petén below 500 m.

Genetic diversity

Limits of genetic stock. The primary genetic stock of *C. pepo* is formed by the groups of edible cultivars (ssp. *pepo*) and ornamental cultivars (ssp. *ovifera*) as well as wild taxa (*C. fraterna* and *C. texana*).

There are a great number of commercial cultivars with particular characteristics which, together with the local varieties referred to which are grown mainly in Mexico, constitute an extraordinary genetic stock. However, in contrast to other species, this diversity does not represent an important source of genes resistant to pests and diseases, since *C. pepo* (including *C. texana*) is probably the species with the greatest susceptibility to the most important viral diseases that attack cultivated species of *Cucurbita*.

Species that might represent a secondary genetic stock are scarce, as most of the attempts at hybridizing *C. pepo* with other wild or cultivated species have required special techniques such as embryo culture; however, good results with hybridization have been achieved in Mexico and the United States.

Germplasm collections. Data obtained from the gene banks show that *C. pepo* is the species of the genus with the second highest number of accessions (1 135). However, this refers only to cultivated and edible forms, since those corresponding to the two closest wild relatives are very scarce and, in fact, those of *C. fraterna* were completed only very recently. The gene banks with the greatest representation of *C. pepo* cultivars are in the United States, Mexico and Costa Rica.

Cultivation practices

In its native area of distribution, *C. pepo* is grown both in maize fields and vegetable gardens as well as in other more intensive systems. In the former case, it is combined with maize, beans and/or with one to three of the other cultivated species of *Cucurbita*, while in the latter system it may be found growing on plots or in small groups, generally combined with other vegetables. Where it is grown commercially, it is generally found as the sole crop, occupying areas of varying size.

In the region of Mixteca Alta, Mexico, and particularly in San Andrés Lagunas, some local variants have been found which are grown under two different sets of conditions and at two different times. One of these is known as heavy rain gourd (calabaza de temporal); it is grown on rocky ground, generally with abundant outcrops of limestone and commonly with little soil – that is, on dry ground. Sowing takes place in April and May, depending on the appearance of the first rains, and the ripe fruit is harvested in October and November. Another variant is known as the bowl gourd (calabaza de cajete); it is grown on ground called *cajete* (bowl), which is very flat and humid and situated in small valleys which are said to have once been occupied by lakes. In this form, it is sown at the start of the driest period of the year (February or March) and the ripe fruit is harvested between July and September.

In Yucatán, the tsol or "mensejo" variety is grown, generally in vegetable gardens or intensive husbandry systems such as those called *conucos* (small farms) and *pachpakal*, and very rarely in maize fields. It is a short-cycle variety; sowing takes place approximately 15 to 20 days after the start of the heavy rainstorms (from May to June); the unripe fruit for use as vegetables is harvested from August onwards, while the ripe fruit is available between September and October.

Prospects for improvement

The three species *Cucurbita argyrosperma*, *C. moschata* and *C. pepo* complement one another in their natural areas of production, which range from 0 to 2 000 m in their region of origin. In the latter, evaluation of the primitive cultivars needs to be stepped up and their germplasm used to develop new cultivars that are more productive and of greater food value, or that are resistant to diseases, especially viruses. As has already been shown in the case of some species, there are also local varieties which differ in their production period. The direct use of these, or of the genes that determine this characteristic, would allow their period of availability at markets to be extended.

The germplasm of the four species of *Cucurbita* should be urgently collected in their area of natural distribution. Introducing varieties present in other areas, such as *C. moschata* varieties which are found in Africa and have a high carotene content, and incorporating them in genetic improvement programmes is also a matter of urgency.

Boosting consumption, whether local or in the form of exports, requires the fruit to possess characteristics adapted to consignment and storage. There is a wide diversity of such characteristics which can be used to produce superior varieties.

Cucurbita spp. offer possible new uses or more intensive uses, which can be widely promoted. One is the preparation of purées or similar foods, for which there would be a very extensive genetic stock for determining organoleptic or nutritional characteristics, resulting in a product superior to the one existing on the markets and which is derived from other products. We ought also to explore the possibility of increasing the use of young stems, which are the part of the plant with the greatest food value because of the amino acid and vitamin content. Varieties which produce more foliage could even be bred for this purpose.

The use of seeds as dried fruit is common in some areas of Mesoamerica and almost unknown in others. The seeds are a good source of protein and oil, and their industrial preparation and marketing should be investigated.

There is still much to be done in terms of the collection, conservation, evaluation and use of regional or local varieties. These tasks are feasible, as the range of these crops is still to be found in the rural communities of the New World. We should not pass up the opportunity of utilizing this material to produce superior varieties and conserve their germplasm for future use.

Cucurbita moschata

Botanical name: *Cucurbita moschata* (Duchesne ex Lam.) Duchesne ex Poiret

Family: Cucurbitaceae

Common names. *English:* pumpkin, winter squash, musky squash, cushaw; *Nahuatl:* tamalayota (Mexico, Colombia [Guerrero]); *Spanish:* calabaza (Mexico), ayote (Guatemala to Costa Rica), auyama (Panama to Venezuela), zapallo (Ecuador, Peru), joko (Bolivia)

Origin, domestication and distribution

It was thought that *C. moschata*, like *Cucurbita ficifolia*, was of Asiatic origin. However, it is now evident that it was domesticated in Latin America, although it is still unclear what the precise area of domestication of either species was. On numerous occasions, it has been reported to be in Mesoamerica and on other occasions in South America, more specifically with its centre of origin in Colombia. The vestiges available are undoubtedly difficult to interpret. The oldest archaeological remains of this species were found in northwestern Mexico (the caves of Ocampo, Tamaulipas) and date from 4900 to 3500 BC. Remains are also known in northern Belize, in Tikal, Guatemala (2000 BC to AD 850), and in Huaca Prieta, Peru (3000 BC).

Electrophoretic analysis of isoenzymes has not provided any substantial evidence. However, it has enabled us to reaffirm the strong relationship between this species and taxa of the *C. argyrosperma* group. Nor is the linguistic evidence very clear: *C. moschata* is known by native names both in the Mesoamerican region (mainly in Mexico) and in South America; this, on the other hand, supports the observation that both regions correspond to two centres of the crop's diversification.

Furthermore, the variation in *C. moschata* does not suggest any region in particular as the centre of origin, since this species is extremely variable in the morphology of its fruit and seeds.

The geographical distribution of the known archaeological remains of *C. moschata* indicate that it has been cultivated for more than 5 000 to 6 000 years. Its spread to other countries, both within Latin America and outside the continent, was certainly very early. This is shown by the existence of the variety called Seminole Pumpkin, grown since pre-Columbian times by indigenous groups of Florida in the United States, and also by its appearance in seventeenth-century botanical illustrations. Such an early spread must have been very continuous and intense since, in the last decade of the nineteenth century, the species was cultivated in India, Java, Angola and Japan.

Uses and nutritional value

In the greater part of *C. moschata*'s native area, its flowers, young stems and young and ripe fruits are eaten as a vegetable. The latter are also commonly used to prepare sweets and as fodder. The seeds are eaten whole, roasted or toasted and are ground into different stews. They have high oil and protein contents (similar to those noted in *C. argyrosperma*) and their consumption in urban areas is also fairly common.

Botanical description

C. moschata is a creeping and climbing plant. It is herbaceous, annual, monoecious, lightly and densely pubescent, with short and long uniseriate trichomes and caulescent vegetative apices that are fairly reflexed. It has slightly angular stems. Its leaves have petioles of 30 cm or more, are broadly ovate-cordate to suborbicular, measure 20 to 25 × 25 to 30 cm, have white spots, are slightly lobate with three to five ovate or triangular lobules, have an obtuse apex that is briefly apiculate, serrate-denticulate margins and three to five ramified tendrils. *C. moschata* has pentamerous, solitary, axillary flowers. The male flowers have 16 to 18 cm pedicels and a very short calyx, are broadly campanulate to pateriform, expanded or foliaceous towards the apex, 5 to 13.5 cm long, with five divisions for up to one-third of their length. The female flowers have thick pedicels of 3 to 8 cm in length, and a globose, ovoid, oblate, cylindrical, piriform, conical, turbinate ovary. They have a very small calyx and sepals that are more often foliaceous than in the males, measure up to 7.5 cm in length and are of thickened style. They have three lobate stigmas. The fruit varies greatly in size and shape (generally following the form of the ovary): smooth or with rounded ribs, rarely verrucose or granulose, with a rind that is both thickened and durable and soft and smooth, and of a very variable colour – light green to uniform dark green or with cream spots, light to dark, or completely white. The flesh is light or bright orange to greenish, ranges from light to very sweet, is soft and generally not fibrous. It has numerous seeds which are ovate/elliptical, measuring 8 to 21 × 5 to 11 mm and which have a yellowish-white surface.

Ecology and phytogeography

In botanical literature, *C. moschata* is reported as being grown mainly in areas of low altitude with a hot climate with high humidity. However, while it is true that this species is preferentially grown within these limits, they do not appear to be strictly adhered to, as variants have recently been found above 2 200 m in Oaxaca, Mexico.

Genetic diversity

Limits of genetic stock. The wide range of altitudes at which *C. moschata* is cultivated within the American continent, the considerable morphological diversity of its seeds and fruit (colour, shape, thickness and durability of the fruit's skin), the existence of varieties with life cycles of different duration as well as the existence of numerous cultivars developed in other parts of the world and of local varieties with excellent agronomic characteristics, clearly indicate that the genetic variation of this species is very extensive.

Some interesting regional varieties for Latin America are those existing on the Yucatán peninsula (and possibly in other regions of Latin America), with two life cycles of different duration, and those cultivated in Guanajuato and Chiapas, in which resistance to some viral diseases was recently found. Among the former, the short-cycle variety commonly grown in Mayan vegetable gardens is of great interest, since it was certainly from this that the most commercially important variety in the region was derived. It should be mentioned that those cultivated in Guanajuato and Chiapas are currently being used in genetic improvement programmes.

With regard to the sources of variation of *C. moschata* cultivars developed outside its area of origin, the best example is that of a cultivar, native to Nigeria, which represents the only source of resistance to certain viral diseases. The possibilities of hybridization that *C. moschata* has shown with other cultivated species (for example, *C. maxima*) enable us to affirm that there are good prospects for the improvement of these crops.

Another part of the genetic stock of *C. moschata* is represented by the numerous commercial cultivars that have been developed, mainly in the United States and to a lesser extent in Brazil. Prominent among these are Butternut Squash, Golden Cushaw, Large Cheese, Tennessee Sweet Potato, Kentucky Field, Menina Brasileira and others. Some of these commercial cultivars also have different levels of resistance and/or susceptibility to certain diseases, which is indicative of the wide genetic variation of this species.

Germplasm collections. *C. moschata* is the best represented of *Cucurbita* in the gene banks of America, in which more than 2 000 accessions have been deposited. These come chiefly from Mexico and Central America and to a lesser degree from South America and other regions of the world. The most important accessions are those from the United States and Costa Rica. Collectively, the accessions are made up of American material, mainly from Central America. For its part, the CIFAP collection in Mexico is possibly the most representative of *C. moschata*'s variation in that country.

Cultivation practices

The different variants of *C. moschata* are grown under traditional, heavy rain agricultural systems. It is possible to find varieties grown in maize fields together with maize, beans and one or two other Cucurbits, or in vegetable gardens and other more intensively managed farmland where they are grown alone or with other species. Sowing is carried out at the start of the rainy season and the development time is approximately five to seven months, although there are varieties with a very short cycle (three to four months) such as those mentioned from the Yucatán peninsula. In the long-cycle varieties, the young fruit to be used as vegetables is harvested approximately three months after sowing, while the ripe fruit for seed is harvested mainly between the sixth and seventh month.

In the Mixe region and other regions of the state of Oaxaca, *C. moschata* is also grown in the cold, dry season of the year on moisture-retaining ground. Cultivation is even carried out with the help of irrigation in some parts of the state of Sonora and some short-cycle varieties have also been observed on the Yucatán peninsula where they are grown for commercial purposes in humid soils or using unusual substrates (henequen fibre waste) and irrigation.

It is likely that varieties such as the ones described, and possibly others, are grown more commonly than is thought or known on the American continent. There are some old references to a considerable variation in Colombia, but its current situation has to be properly documented and evaluated.

Cucurbita ficifolia

Botanical name: *Cucurbita ficifolia* Bouché

Family: Cucurbitaceae

Common names. *English:* fig leaf squash, Malabar gourd, cidra, sidra; *Nahuatl:* chilacoyote (Mexico, Guatemala); *Spanish:* lacoyote (Peru, Bolivia, Argentina), chiverri (Honduras, Costa Rica), victoria (Colombia)

Origin, domestication and distribution

At the end of the last and the beginning of this century, some authors were suggesting an Asiatic origin for *Cucurbita ficifolia*. Since the middle of this century, the consensus has been that it is of American origin. However, its centre of origin and domestication are still unknown. Some authors have suggested Central America or southern Mexico as places of origin, while others suggest South America, and more specifically the Andes. Biosystematic studies have been unable to support the Mexican origin suggested by the distribution of common names derived from Nahuatl throughout America.

Archaeological vestiges point to a South American origin, since the oldest remains are Peruvian, but biosystematics have not been able to confirm this hypothesis either.

Attempts at obtaining hybrids beyond the first generation with the other four cultivated species have failed and the few results obtained have required the use of special techniques such as embryo cultivation. These results have been corroborated by other studies which reveal that *C. ficifolia* shows considerable isoenzymatic and chromosomic differences compared with all the taxa of the genus.

In addition to the foregoing observations, the recent discovery that *Peponapis atrata* does not appear to be a specific pollinator of *C. ficifolia* has led to the suggestion that the wild ancestor of this species might have been a still undiscovered species whose habitat could be the eastern region of the Andes. This is why the possibility of using wild (or cultivated) species in future programmes for the genetic improvement of this crop and their use in the improvement of other cultivated species of the genus is still remote. The importance of these programmes lies in the fact that collections have been identified which are resistant or completely immune to the attack of different viruses that severely affect other cultivated species.

The cultivation of *C. ficifolia* ranges from northern Mexico to Argentina and Chile. Its spread to Europe (France and Portugal, for example) and Asia (India) apparently began in the sixteenth and seventeenth centuries when its fruit reached the Old World from South America and India. Since then, its cultivation has spread to many other parts of the world (Germany, France, Japan and the Philippines).

Uses and nutritional value

The different parts of *C. ficifolia* plants are put to various food uses throughout its distribution area in America. The unripe fruit is eaten boiled as a vegetable, while the flesh of the ripe fruit is used to prepare sweets and soft or slightly alcoholic drinks. The seeds are also greatly valued and in Chiapas, Mexico, they are used with honey to prepare desserts known as *palanquetas*.

In some regions of Mexico (and perhaps other countries of the continent), the young stems (or "runner tips") and also the flowers are eaten as a cooked vegetable, while the ripe fruit is used as fodder for domestic animals. The latter is the commonest use in the Old World where this species has been introduced.

The most important nutritional value is found in the seeds which provide a considerable source of protein and oil. As indicated by its white colour, the flesh of the fruit is deficient in beta-carotene, and has a moderate quantity of carbohydrates and a low vitamin and mineral content.

Recent research in Chile has shown that some proteolytic enzymes from the flesh of *C. ficifolia* fruit can be used to treat waste water from the industrial processing of foods derived from fish. This discovery is of great interest because of the reduction in costs that these industries could achieve by using enzymes which would replace those imported at present.

In Japan and Germany, it has been used as a support or rootstock for the winter production of cucumber (*Cucumis sativus* L.) in greenhouses.

Botanical description

C. ficifolia is a creeping or climbing plant, monoecious, annual – although persistent for a certain period, giving the impression of being a short-lived perennial – without swollen reserve roots. It is resistant to low temperatures but not to severe frosts. It is villose to softly pubescent, with some short, sharp spines dispersed over the vegetative parts. It has five vigorous, slightly angular stems and leaves with 5 to 25 cm petioles that are ovate-cordate to suborbicular-cordate, with or without white spots on the surface, and have three to five rounded or obtuse, apiculate lobules, the central one bigger than the lateral ones. They have denticulate margins and three to four ramified tendrils. The flowers are pentamerous, solitary, and axillary. The male flowers are long and pedicellate, have a campanulate calyx that is 5 to 10 mm long and almost as wide, 5 to 15 × 1 to 2 mm linear sepals and a tubular-campanulate corolla that is rather broader towards the base, 6 to 12 cm long and yellow to pale orange. They have three stamens. The female flowers have sturdy peduncles, 3 to 5 cm long, an ovoid to elliptical, multilocular ovary; sepals that are occasionally foliaceous and a corolla that is somewhat larger than that of the male flowers. They are of a thickened style and have three lobate stigmas. The fruit is globose to ovoid-elliptical, with three colour patterns: *i)* light or dark green, with or without longitudinal white lines or stripes towards the apex; *ii)* minutely spotted white and green; *iii)* white, cream or flesh white. The flesh is sweet and the seeds are ovate-elliptical, flattened, 15 to 25 × 7 to 12 mm, and a dark brown to black or creamy white colour.

Ecology and phytogeography

C. ficifolia is grown over a wide distribution area from 1 000 to almost 3 000 m in practically all the mountain ranges of Latin America. The restriction of cultivation to areas of considerable altitude is a distinctive characteristic of *C. ficifolia* compared with other cultivated species of the genus, which can generally grow in a wider range of ecological conditions (in the case of *C. pepo* and *C. moschata*, from 8 to 2 300 m).

Genetic diversity

Limits of genetic stock. In view of the reproductive incompatibility of *C. ficifolia* with the other species of the genus, it may be said that its genetic stock is limited to itself. However, in other respects this species is much less different than are other cultivated species of the genus, and there are no commercial cultivars. Among its most notable morphological variations are the coloration and size of its fruit and seeds. The scant morphological variation of this species is consistent with that observed in the patterns of isoenzymes studied so far.

From the agronomic point of view, it is possible to acknowledge the existence of some genetic diversity for *C. ficifolia* for two reasons:

- it is cultivated in a wide geographic range where conditions are only relatively uniform as regards altitude, but different from the point of view of other local ecological factors;

- it is grown both without distinction both under agricultural systems with high competition (for example, heavy rain maize fields) and under others with less competition or which allow a more intensive cultivation (for example, maize fields cultivated in the dry season on humid ground, vegetable gardens and plots).

However, none of these aspects has so far been evaluated.

Productivity, as regards the number of fruits and the quantity of seeds per fruit, is another aspect which possibly reflects the genetic diversity of the species and which, again, is insufficiently documented. Field observations have revealed that some medium-sized fruits contain 500 or more seeds and that each plant can produce more than 50 fruits.

Germplasm collections. Accessions of *C. ficifolia* germplasm are the least abundant of all those existing for the cultivated species of *Cucurbita*. In addition, they are not very representative of its geographical distribution. There are 338 accessions to be found in America's gene banks; these, added to another 82 deposited with institutions of countries outside the continent, make a total of 420. However, many of the accessions are duplicates, which reduces their number by about half.

Cultivation practices

C. ficifolia is a crop grown mainly in traditional heavy rain agricultural systems, which shows that the start of the rainy season corresponds to the sowing time, while harvesting takes place from the end of September (young fruit and flowers for vegetables) to December or January (ripe fruit for seed and flesh). In some regions of Mexico, such as Mixteca Alta in Oaxaca, it has been found that, in addition to being cultivated during the rainy season on heavily rain-fed terrain, this species is also grown during the dry season on more humid ground (valleys or areas where the soil drainage is slightly deficient). In these cases, sowing is carried out in the early months of the year and the crop is harvested from the dry season (April) until that corresponding to summer (May to July). This has made it possible to ensure almost uninterrupted production throughout the year.

The only form of propagation is the sowing of seed, together with one of the traditional crops of this type of agriculture (maize, bean and other species of *Cucurbita*), or else cultivation in vegetable gardens along with other species or by itself. The ripe fruit is harvested and selected for seed. It can be stored for long periods (18 to 20 months) and it is frequently seen drying on the roofs of farmers' houses.

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Chayote (*Sechium edule*)

Botanical name: *Sechium edule* (Jacq.) Sw.
Family: Cucurbitaceae
Common names. *English:* chayote, Madeira marrow, vegetable pear; *Nahuatl:* chayote (Mexico, Nicaragua, Costa Rica, Panama); *Spanish:* cidrayota (Colombia), gayota (Peru), huisquil, güisquil or uisquil (Mexico [Chiapas], Guatemala, El Salvador), papa del aire, cayota (Argentina); *Portuguese:* chocho, chuchu, xuxu, machiche, machuchu (Brazil); *French:* christophine, mirliton (Haiti, Guadeloupe, Bermuda, Trinidad and Tobago, United States [Louisiana], French Guyana)

Origin and domestication

Unlike other crops, there is no archaeological evidence to indicate how long *S. edule* has been cultivated. Its fleshy fruit, which has a single seed with a smooth testa, does not allow it to be preserved and, as far as is known, no pollen grains or other structure of this species have been identified on archaeological sites.

Chroniclers from the time of the conquest record that, in Mexico at least, the chayote has been cultivated since pre-Columbian times. As regards linguistic references, the common names of native origin are concentrated mainly in Mexico and Central America. Exploration records concur in the finding that the widest variation of *S. edule* under cultivation is found between southern Mexico and Guatemala. The geographical distribution of the wild relatives of *S. edule* also testifies to the Mesoamerican origin of this crop.

The closest relatives to *S. edule* are:

- the so-called wild forms of *S. edule*, the taxonomic positions of which are unresolved since they are distributed in an apparently natural way in the Mexican states of Veracruz, Puebla, Hidalgo, Oaxaca and Chiapas;
- *S. compositum*, a species restricted to southern Mexico (Chiapas) and Guatemala;
- *S. hintonii*, a species endemic to Mexico, until recently considered to be extinct and which grows in the states of México and Guerrero and possibly in Jalisco;
- a new species of the *Sechium* selection which grows in the north of the state of Oaxaca.

From the foregoing it has been possible to corroborate the fact that *S. edule* is a species which was undoubtedly domesticated within the cultural area of Mesoamerica, and specifically in the region lying between southern Mexico and Guatemala.

Chayote cultivation is widely distributed in Mesoamerica. It was introduced into the Antilles and South America between the eighteenth and nineteenth centuries. The first botanical description mentioning the name *Sechium* was in fact done in 1756 by P. Brown who referred to plants

The author of this chapter is R. Lira Saade (National Herbarium of Mexico, Mexico City), who wishes to thank E. Valverde and E. Chinchilla (CINDE, Costa Rica).

grown in Jamaica. During this same period, the chayote was introduced into Europe whence it was taken to Africa, Asia and Australia, while its introduction into the United States dates from the late nineteenth century.

Uses and nutritional value

The chayote is used mainly for human consumption. The fruit, stems and young leaves as well as the tuberized portions of the roots are eaten as a vegetable, both alone and plain boiled, and as an ingredient of numerous stews. Because of its softness, the fruit has been used for children's food, juices, sauces and pasta dishes. In Mexico, an attempt has been made to increase the life of the fruit by drying it. The results have been positive and have enabled jams and other sweets to be prepared while also producing dried fruit which can be used as a vegetable after a certain time. Because of their flexibility and strength, the stems have been used in the craft manufacture of baskets and hats. In India, the fruit and roots are not only used as human food but also as fodder.

The edible parts of *S. edule* have a lower fibre, protein and vitamin content than other plants. However, the calorie and carbohydrate content is high, chiefly in the case of the young stems, root and seed, while the micronutrients and macronutrients supplied by the fruit are adequate. The fruit and particularly the seeds are rich in amino acids such as aspartic acid, glutamic acid, alanine, arginine, cysteine, phenylalanine, glycine, histidine, isoleucine, leucine, methionine (only in the fruit), proline, serine, tyrosine, threonine and valine.

The chayote also has medicinal uses; infusions of the leaves are used to dissolve kidney stones and to assist in the treatment of arteriosclerosis and hypertension; infusions of the fruit are used to alleviate urine retention. The cardiovascular properties of the infusions of leaves have been tested in modern studies, while their great effectiveness in curing kidney diseases has been known since colonial times on the Yucatán peninsula, where these ailments are very common.

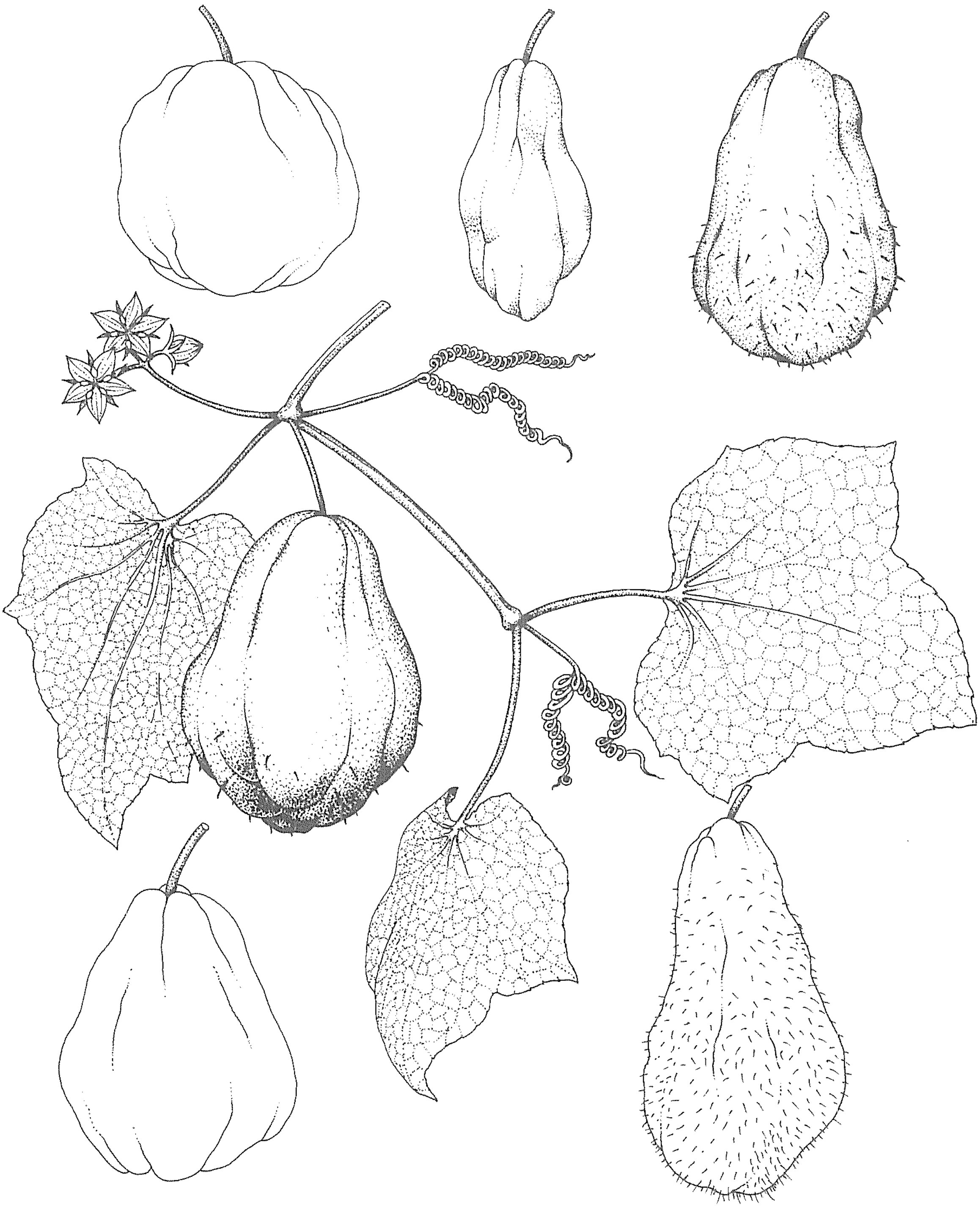
Botanical description

S. edule is a perennial, monoecious climber, with thickened roots and slender, branching stems up to 10 m long. Its leaves are on sulcate petioles of 8 to 15 cm in length, they are ovate-cordate to suborbicular, measure 8 to 18 × 9 to 22 cm, are slightly lobate (with three to five angular lobes) and have minutely denticulate margins and three to five divided tendrils.

The flowers are unisexual, normally pentamerous, coaxillary and with ten nectaries in the form of a pore at the base of the calyx. The staminate flowers grow in axillary racemose inflorescences that are 10 to 30 cm long, and the groups of flowers are distributed at intervals along the rachis. The calyx is patteliform and 5 mm wide, the sepals triangular and 3 to 6 mm long, the petals triangular, greenish to greenish-white and measure 4 to 8 × 2 to 3 mm. There are five stamens, and the filaments are fused almost along their total length, forming a thickened column which separates at the apex into three or five short branches. The pistillate flowers are normally on the same axilla as the staminate flowers; they are usually solitary but are occasionally in pairs; the ovary is globose, ovoid or piriform, glabrous, inerm and unilocular; the perianth is as in the staminate flowers but has slightly different dimensions; the styles are fused in a slender column and the nectaries are generally less evident than in the staminate flowers. The fruit is solitary or rarely occurs in pairs; it is viviparous, fleshy and sometimes longitudinally sulcate or crestate; it is of very different shapes and sizes, indumentum, number and type of spines; it is white and yellowish, or pale green to dark green with a pale green to whitish flesh that is bitter in the wild plants and

FIGURE 6

Chayote (*Sechium edule*) fruit shapes



not bitter in the cultivated ones. The seed is ovoid and compressed with a soft and smooth testa.

Ecology and phytogeography

S. edule is grown traditionally in many regions of the world, preferably between 800 and 1 800 m altitude. In many regions there are variants adapted to cultivation at sea level (in Rio de Janeiro and Yucatán); in other regions it occurs above 2 000 m (in Bolivia and in the states of Oaxaca and Chihuahua in Mexico). The wild taxa closest to *S. edule* show a similar distribution of altitudes, since they grow between 50 and 2 100 m. The chayote is cultivated in a more intensive way and for commercial purposes in Costa Rica, Guatemala, the Dominican Republic and Mexico. The range cultivated is minimal and always in accordance with consumer requirements.

The floral biology of *S. edule* has been studied in detail: there are various patterns in the structure and sexual expression of the staminate and pistillate flowers, which seem to be determined by genetic, environmental and seasonal factors and by the age of the plants.

Pollination is entomogamous. Among the most efficient pollinators are species of native bees of the genus *Trigona*, chiefly in areas of medium and low altitudes and which are free from pesticides, and the honeybee (*Apis mellifera*) on commercial plantations where the use of pesticides is very frequent. Secondary pollinators include wasps of the genera *Polybia*, *Synoeca* and *Parachartegus*.

The fruit of *S. edule* is viviparous, viz. the seeds germinate inside the fruit even when it is still on the plant. This characteristic does not occur in any of the wild species, in which the seeds germinate asynchronically after falling to the ground. A possible explanation for the viviparism of the cultivate species is that the process of domestication may have resulted in suppression of the dormancy mechanisms.

Genetic diversity

Few cultivated species display the great diversity of shapes, sizes, ornamentation, armature, indumentum and colours as those found in the fruit of the *S. edule*. However, this diversity, which is present in the most varied combinations, has made it difficult to define cultivars. When reference is made to the different types of *S. edule*, therefore, it is rather in connection with local races or variants. In addition to morphological diversity, variants exist in the fruiting periods. An example of this has been observed in Oaxaca and Chiapas where local variants can yield between one and four harvests a year. This type of variation has also been cited in the case of other regions.

The considerable diversity farmed by traditional growers contrasts with the relative homogeneity observed in fruit produced on commercial plantations. In these cases, the fruit must comply with the quality requirements demanded by the market: piriform, light green, smooth, about 15 cm long and 450 g in weight; with no physical damage or blemishes caused by pathogens; and with a suitable texture and sweet and pleasant flavour.

The wild relatives closest to *S. edule* are *S. compositum* and *S. hintonii*, whose distribution area is in Mexico and Guatemala. Because of a lack of agronomic evaluations, these species have not been used in genetic improvement programmes which are so necessary in the search for sources of disease resistance.

Germplasm collections. The germination characteristics of *S. edule* seeds do not allow them to be preserved using simple, orthodox methods. This means that the specimens have to be preserved in field collections which require careful handling.

This type of limitation is evidenced by the disappearance of some of the few collections of the genus *Sechium*. Between 1988 and 1990, the biggest collection of cultivated *S. edule* in the world (at CATIE in Turrialba, Costa Rica) as well as other smaller but equally important collections (for example at CIFAP in Celaya, Mexico) were lost. Fortunately, there are still institutions in the world that are endeavouring to preserve this important genetic stock, at least insofar as the variation of the cultivated species is concerned. Thus, in Mexico there is the collection in the hands of the UACH in Veracruz, with around 150 specimens of cultivated types from Puebla, Veracruz, Oaxaca and Chiapas. This is the only collection which currently preserves plants of some of the most important wild relatives of the chayote, such as *S. compositum* and the wild types of *S. edule*. Two other institutions caring for collections of *S. edule* are the Instituto Superior de Ciencias Agropecuarias of Nicaragua (Centro Experimental Campos Azules) and the Centro Nacional de Pesquisas de Hortalizas, EMBRAPA, Brazil.

Cultivation practices

S. edule is grown in the traditional way on family plots and in backyards and vegetable gardens. The viviparous characteristic of its fruit is familiar to peasant farmers, so that fruit selected for consumption is kept – without being allowed to germinate – by a small cut or puncture made in the embryos, while those selected for seed are simply allowed to ripen until it is decided to plant them.

The normal and most effective form of propagation is from seed. The most widespread sowing practice consists of planting one or more whole fruits. However, on some smallholdings the seed is carefully removed and sown in pots or other media that enable it to be handled for subsequent transplantation in the final sowing plot.

In areas of traditional production, the sowing plot is prepared beforehand by making a hollow in the soil that is big enough to allow the roots to attain maximum development. Next to the sowing plots, a frame of wood or other materials is commonly erected so that the plant can grow on it quickly. For the same reasons, sowing is also frequently carried out close to a tree. During the first weeks of development, the amount of care given is relatively high (irrigation, fertilization with animal or chicken manure, etc.), although attention to the root (protection against physical damage and application of organic fertilizers) is considered of great importance throughout the plant's life cycle.

Sowing can be done at any time of the year, although it generally takes place at the beginning of the rainy season. The average length of the plants' productive cycle is three years or, in exceptional cases, eight.

On commercial plantations, sowing is carried out using rooted cuttings or selected seed. The plants are sown on permanent beds with trellises and are laid out at distances that allow the easiest possible harvesting, transport to cold-storage rooms and packaging. On the commercial type of plantations, chemical and foliar fertilizers are generally used as well as herbicides and nematicides. The leading commercial producer and exporter of chayote fruit is Costa Rica, followed by Guatemala, Mexico and the Dominican Republic.

Prospects for improvement

In spite of the fact that the whole of the *S. edule* plant can be used and with numerous applications (parts of the plant are used for different purposes), in several countries the majority of these uses have not become widespread and ways have not been devised to make them accessible to sectors of the population other than the peasant community.

The most widespread uses at all levels is that of the fruit as a table vegetable and in the preparation of some industrialized foods. Commercial demand requires a morphologically homogeneous production which rules out the possibility of the considerable range of fruit produced under traditional cultivation systems appearing on the market. However, as the standards required for export are very different from those accepted for the product for local consumption, it is not very likely that the usual varieties will be abandoned and that a serious genetic erosion will occur in the species. A plan to intensify and diversify *S. edule* production would have to include the following projects:

- The establishment of permanent gene banks in several localities of Mesoamerica to maintain varietal diversity, wild populations and related congeners. These collections can be used to evaluate resistance to diseases, type of growth and organoleptic characteristics of the fruit. They will allow growers to be supplied with new sowing material and will be used as a basis for genetic improvement.
- Programmes for selecting varieties with a high root yield or a high production of young stems. Both are popularly accepted consumer items, with a high nutritional value and potential use as a basic material in agro-industries.
- The development of vegetative propagation methods that will provide growers with sowing material at reasonable prices.
- Basic studies on the most important diseases (*Ascochyta phaseolorum*, *Mycovellosiella cucurbiticola*, *Fusarium oxysporum* and complexes of these and other species), particularly those which attack the fruit and which cause 35 to 40 percent of the rejects in commercial production.
- Identification of problems in postharvest handling, packaging and storage during the marketing process.

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Custard apples (*Annona* spp.)

There are an estimated 2 200 species of Annonaceae in the world. These include numerous fruit-trees, especially of the genera *Annona* and *Rollinia*; the majority of *Annona* species and all the *Rollinia* species originate from the New World.

Many of these species were carefully cultivated by indigenous peoples in Mesoamerica, the inter-Andean valleys, the Amazon region and other areas. Other Annonaceous fruits of the New World include species of *Asimina*, *Duguetia*, *Fusaea* and *Porcelia*. These fruit-trees have a considerable diversity and degree of adaptation to different environments and are valuable material for hybridization, selection and vegetative propagation studies. The high nutritional value of the fruit, its very distinct flavours and aromas and its attractive shapes and colours justify these efforts.

There are three species, *Annona cherimola*, *A. muricata* and *A. squamosa*, which are marginal in several regions of tropical America; in other regions, the technology for producing and handling the product has been developed to such a degree that they cannot really be included in this category. The known techniques and selected cultivars can be extended to regions where cultivation is still underdeveloped. Another three, *A. diversifolia*, *A. reticulata* and *A. scleroderma*, however, have been marginalized in spite of their intrinsic value and potential as fruit-trees.

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The fruit of the Annonaceae must not be seen solely as a luxury item for rich consumers, but also as part of the diet of indigenous populations. This fruit is not only special because of its good flavour; it is also highly nutritional. Its food value varies considerably, but most forms have an abundance of carbohydrates, proteins, calcium, phosphorus, iron, thiamine, niacin and riboflavin, while some are rich in magnesium, ascorbic acid and carotene. If they were plentiful and sold at reasonable prices, they would considerably improve the nutrition of many people.

Annona cherimola Miller, the cherimoya, is thought to originate from cold but frost-free valleys of the Andes at an altitude of between 700 and 2 400 m.

Excellent cultivars are known, all produced by vegetative propagation, which are planted on a commercial scale in Spain, Chile, Australia, Israel, the United States (California, Florida) and the island of Madeira. The fruit is sold in the supermarkets of many countries and is highly regarded.

The commercial cultivars include Bay Ott, Chaffey, Dr White, Libby, Nata, Orton and Spain.

In the regions where the cherimoya is still a marginal crop, new methods must be applied: artificial pollination, grafting of superior cultivars either on to stock of the same species or on to stock of *A. squamosa* or *A. glabra*; the control of anthracnosis and seed-boring insects; the control of green leafhoppers; and fruit handling and packaging.

A. muricata L. (*English:* soursop; *Spanish:* guanábana; *Portuguese:* graviola) is possibly native to the Antilles and to the northern part of South America. It grows between 0 and 1 000 m altitude. Its commercial production has been developed in Brazil, Venezuela, Costa Rica and other countries for local consumption and export. Cultivation practices have been established in the production areas mentioned; they include the control of insects and diseases and protection of the fruit in plastic bags. There is a great deal of variation in fruit size and sugar content. Trees of higher quality or resistance must be grafted on to stocks of the same species of *A. purpurea* and *A. montana* or, with great difficulty, on *A. glabra*.

A. squamosa L. (*English:* sugar apple, sweetsop, custard apple; *Spanish:* sarumuyo, anón; *Portuguese:* ata, pinha) seems to be native to southeastern Mexico, in dry areas and between 0 and 1 000 m, although it grows well in regions of medium humidity. It has spread throughout the tropics and displays great variability in India. It is propagated by seed with satisfactory results; however, commercial cultivars are grafted. Of these, Red Sugar, with a red skin and white flesh, is recommended. The main problems are seed-boring insects, the green leafhopper, the tendency towards mummification of the fruit and harvesting and packaging difficulties caused by the fruit's lack of firmness.

The name "atemoyas", derived from "ata" (in Portuguese) and "cherimoya", is given to hybrids between these two species. Several cultivars are known which are sown commercially in the United States (Florida) and Australia. The best atemoyas combine adaptation to low altitudes and hot climate and the high productivity and good flavour of *A. squamosa* with the firm skin, low flesh/seed ratio and the flavour and aroma of *A. cherimola* so that, from the standpoint of quality and packaging, the product is comparable to the best cherimoyas, although it has a higher sugar content. At present, crosses are being made between cultivars of cherimoya and *A. squamosa* Red Sugar and M-2, with the aim of obtaining atemoyas with red- or pink-skinned fruit, which is more attractive than the green fruit of those currently available. The most famous green cultivars are Gefner in Israel and the United States and African Pride in Australia.

Annona diversifolia

Botanical name: *Annona diversifolia* Saff.
Family: Annonaceae
Common names. *English:* ilama; *Spanish:* anona blanca; *other:* ílama, ilamatzapotl, izlama, papausa

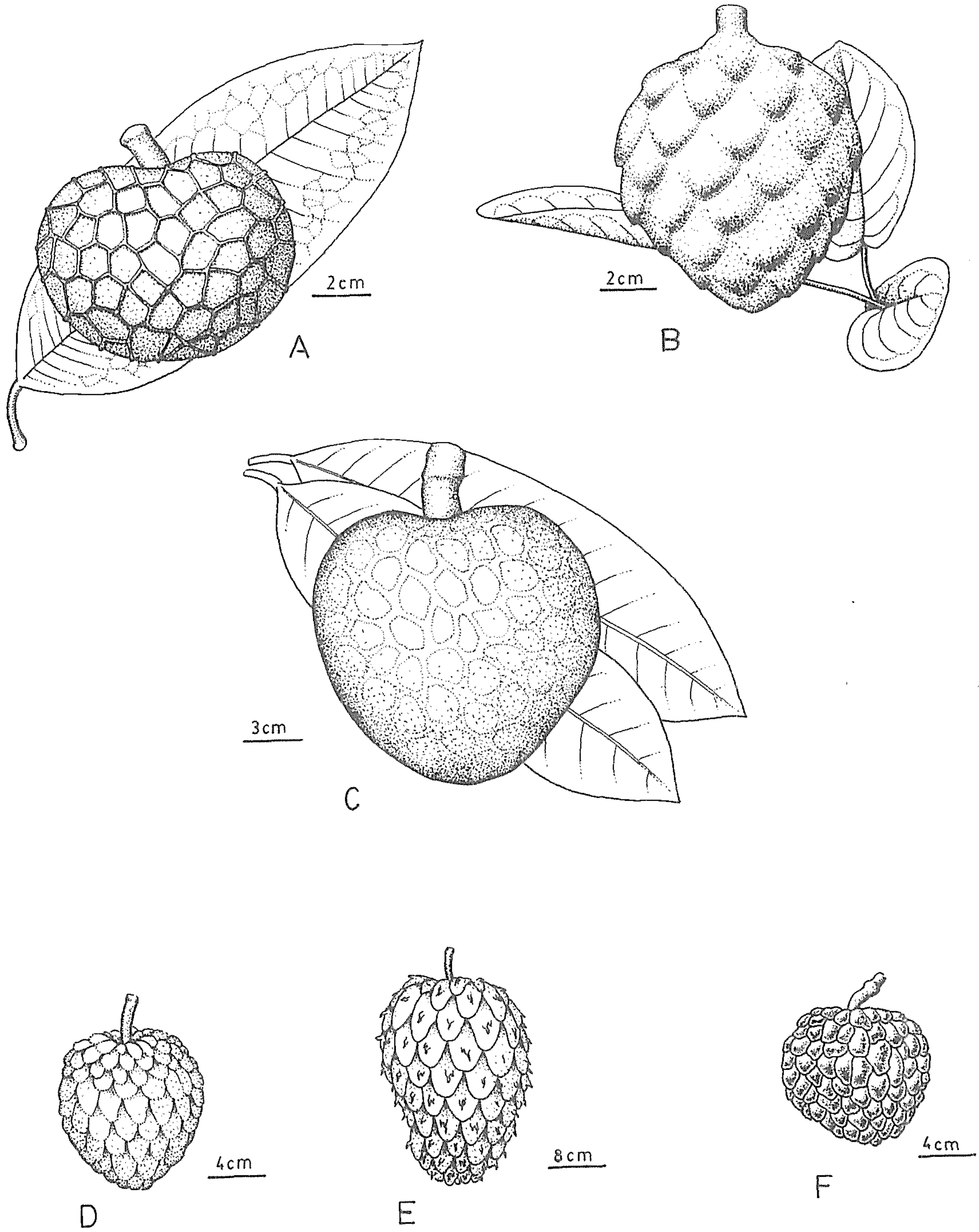
This fruit-tree, which is very highly regarded in its area of origin, has not been developed as it deserves, since it is virtually planted exclusively by indigenous peoples. Although it is greatly esteemed and fetches a good price on the markets of Guatemala, its cultivation does not attract other agricultural owners, nor do the latter obtain bank credit for this tree, whereas they do obtain it for exotic fruit-trees. Other factors that add to its neglect are: the tree's low productivity; the difficulty of seed germination (although methods to encourage germination artificially are already known); and the short shelf-life of the fruit at the markets (two to three days at ambient temperature). If it is left to ripen on the tree, the fruit splits, but if it is picked in this state and stored at normal temperature, the splits scar over. In Guatemala, it is customary to pick the fruit split in this way and to ripen them subsequently in crates or other closed places.

Botanical description

A. diversifolia is distinguished from other species of *Annona* in that it has two classes of leaf:

FIGURE 7

Custard apples: A) *Annona scleroderma*; B) *A. diversifolia*; C) *A. reticulata*; D) *A. cherimola*; E) *A. muricata*; F) *A. squamosa*



the usual obovate, glabrous leaves with a petiole; and leaves in the form of round, deciduous bracts without a petiole, which grow on the base of the small branches. The undersides of the leaves, small branches and fruit have a powdery, whitish appearance, which is more noticeable in the white-fleshed varieties.

The flowers have three outer petals that are 2 to 5 cm long, and three minute inner petals; the colour is a varietal characteristic and ranges from pink to purplish red.

The fruit, which is about 12 cm long, has white, pink or reddish flesh, with a typical aroma and a sweet, exquisite flavour which, according to most people, is superior to that of the cherimoya. The fruit is very resistant and sometimes completely immune to attack from seed-boring insects.

Ecology and phytogeography

The ilama grows between 0 and 1 800 m on the Pacific slope from central Mexico to El Salvador, but it is sown more intensively between 200 and 600 m in southwestern Guatemala. This region has a pronounced dry season (December to March), with an annual rainfall of between 1 000 and 1 400 mm and very fertile volcanic soils.

Genetic diversity

A. diversifolia is grown alone in vegetable gardens with few trees, and a wide variability is noted. This is particularly expressed in the characteristics of its fruit: its colour (see list of cultivars); its texture, which can range from slightly pasty to juicy, soft or with concentrations of harder grain; and its sweet taste, with a typical aroma. Following is a list of *A. diversifolia* cultivars:

- **Fairchild, Rosendo Pérez, Guillermo** and **Gramajo** have a thick-skinned, greyish green fruit with prominent round areoles and pink flesh. Rosendo Pérez and Gramajo have big fruit. (These cultivars have been bred for Florida.)
- **Imery** (bred in El Salvador) has big fruit that has a thinner skin, low prominences, is pinkish green (greyish brown when ripe) and has pink flesh with bolder spots.
- **Pajapita** has a soft, pink surface (brown when ripe) and bright-pink flesh.
- **Nilito** has a slightly irregular surface, which is bluish green, and red flesh.
- **Roman** has smaller fruit with a hard skin, which is bluish green with pink spots, and purple flesh.
- **Genova white** has a smooth, thin, whitish green skin, and white flesh.
- **Efrain** has up to 200 fruits per tree.

Guatemalan markets sell an ilama that has bluish green fruit, with swirling marks such as those in a Van Gogh painting, and delicious bright-red flesh which is easily separated from the seeds. The trees from which this fruit comes have not yet been studied.

The only region to be evaluated as regards genetic erosion is southwestern Guatemala, where the problem does not seem to be serious. There are no gene banks, nor are any preservation techniques known other than live collections. The most promising areas for future exploration are southwestern Guatemala and the state of Chiapas in Mexico.

Cultivation practices

The ilama is only grown together with other fruit-trees, on the patios of houses or on smallholdings belonging to indigenous peoples. It is always propagated by seed with a long dormancy period which is difficult to interrupt. The seeds should not be sown without being pretreated to interrupt dormancy, such as soaking them in a solution of gibberellic acid, exposing them to the sun, immersing them in hot water or storing them for two to three months.

Prospects for improvement

In the case of *A. diversifolia*, urgent work is needed in the following areas:

- vegetative propagation, by grafting, of the best varieties, using various stocks and grafting methods;
- effective interruption of seed dormancy;
- picking and commercial handling of the fruit;
- increasing the production period (July-August) by selecting early and late varieties;
- the establishment of gene banks, at least in localities of the Pacific area of Central America and Mexico;
- stepping up exploration of the species' production areas in Mexico, Guatemala and El Salvador;
- hybridization with other species of *Annona* for the production of more adaptable varieties;
- research on stock of the related wild species *A. macroprophyllata*, from Guatemala and El Salvador;
- research into the possibility that the absence of mycorrhizae or other soil factors are responsible for the growth of this species in other regions of Mesoamerica with favourable climate and soils, and into the possible use of grafting in these cases.

Annona reticulata

Botanical name: *Annona reticulata* L.

Family: Annonaceae

Common names. *English:* bullock's heart, custard apple, sugar apple; *Spanish:* anona, anona colorada, anona rosada, corazón; *Portuguese:* coração de boi; *other:* cahuex, pox, qualtzapotl, tzumuy

Although it is said that *A. reticulata* is a native of the Antilles, the presence in Guatemala and Belize of a wild variety, *A. reticulata* var. *primigenia*, and also of a very wide variability of cultivars suggests that this zone is the species' area of origin. It has been introduced in other regions of the American tropics and Southeast Asia, without achieving a level of importance comparable to that of *A. cherimola* or *A. squamosa*.

Of the causes of *A. reticulata*'s current marginalization, two seem to be the most notable: reproduction by seed, which results in many trees producing much smaller fruit; and the attack of the seed weevil which lays its eggs in the young fruit. When the adult insect develops, it bores tunnels through the flesh, causing mycotic infections and a consequent deterioration of the fruit.

The most attractive aspects of this species are: its pleasant-tasting fruit, which is generally sweet and creamy; the relatively small volume taken up by the skin and seed; and the plant's modest soil requirements.

Botanical description

A. reticulata is a low tree with an open, irregular crown and slender, glabrous leaves which in some varieties are long and narrow, 10 to 20 × 2 to 7 cm, straight and pointed at the apex; and in other varieties wrinkled and up to 10 cm wide. The flowers are generally in groups of three or four, with three long outer petals and three very small inner ones. The fruit is heart-shaped or spherical and 8 to 15 cm in diameter; according to the cultivar, the flesh varies from juicy and very aromatic to hard with a repulsive taste. There is a wide variability in the presence of groups of hard cells that are similar to grains of sand. Both the outside and inside colour varies according to the cultivar.

Ecology and phytogeography

A. reticulata grows between 0 and 1 500 m in the areas of Central America that have alternating seasons, and has spread to South America. However, it is in the former region that the varieties previously classified as species are to be found: *primigenia*, already mentioned; and *lutescens*, the yellow custard apple which grows from Mexico to Costa Rica.

Genetic diversity

In Florida (United States) superior cultivars have been selected, especially from Belize and Guatemala. They differ in the characteristics of their fruit and even in their compatibility with stocks.

- **Tikal** is of excellent quality and medium yield; its flesh is bright-red, except in the white areas surrounding the seeds.
- **Canul** has a medium fruit with a waxy, shiny dark-red surface and purplish red flesh; it is very aromatic and deliciously sweet with few concretions of hard cells.
- **Sartenaya** has a medium fruit with a waxy, shiny red surface and pink flesh with a magnificent taste and texture. Although the fruit is not as attractive in appearance as that of the previous two cultivars, the tree is sturdier.
- **San Pablo** has a long, large fruit with an opaque, light-red surface. The flesh is dark-pink with a good aroma and taste. It is a vigorous, productive cultivar.
- **Benque** has a big conical fruit with a dark-red surface and very tasty dark-pink flesh.
- **Caledonia** has a small fruit with a dark surface; it is very attractive to cochineal insects (*Philophaedra* sp.), which are not very common in other varieties. The flesh is pink and has an excellent taste.
- **Chonox** has a medium fruit with a red skin and juicy, very tasty pink flesh; it is very productive and, for this reason, often has low-quality fruit. It produces abundant flowers in groups of up to 16.

No selections have been made from yellow custard apple and there are apparently no great risks of genetic erosion. It is possible that more intensive exploration in Belize, Guatemala and El Salvador might allow new cultivars to be found.

Cultivation practices

A. reticulata is generally propagated by seed, the germination rate of which ranges from low to medium. Grafting is usually done on stock of the same species. The fruit is harvested after its colour changes patterns although in some cultivars this does not occur and ripeness is determined by feel. The skin is very thin and the fruit must therefore be handled carefully. Most fruit is produced for family consumption and it is not commonly found on the markets outside Guatemala. The commercial future of this species depends on two factors: the establishment of grafted trees of high-yielding cultivars with fruit of a high quality and good appearance; and the adoption of control practices such as using protective bags or eradicating seed-boring insects.

Annona scleroderma

Botanical name: *Annona scleroderma* Saff.
Family: Annonaceae
Common names. *English:* poshte; *Spanish:* chirimoya, anona del monte; *other:* cawesh, cahuex, poshté

A. scleroderma is one of the least-known fruit-trees of the genus; it is grown mainly in south-western Guatemala and is notable for the structure of its fruit which, unlike the other cultivated species, has a very tough skin, allowing it to be handled much more easily and making it resistant to insect attack. The fruit may be cut and the flesh removed with a spoon. Its potential value is in its high-quality flesh, hard skin and high yield. It could become an export item and a product for wide local consumption.

However, the height of the tree (which does not facilitate fruit harvesting), the fact that the fruit is attacked by birds and the defoliation caused by wind are an obstacle to exploitation of this species.

Botanical description

A. scleroderma is a tall tree which reaches 15 to 20 m and has tough, lanceolate leaves measuring 10 to 25 × 5 to 8 cm. They are shiny on the upper side, slightly pubescent on the underside and have fragile, 3 cm long petioles. The flowers are greenish yellow, the outer petals have a longitudinal prominence which arises in the small branches or in groups in the old part of the thick branches. The fruit occurs in compact spherical groups, is 5 to 10 cm in diameter and generally falls off when ripe, without a noticeable colour change. The cream-coloured flesh has a bittersweet flavour and a soft texture.

Ecology and phytogeography

This species apparently grows wild on the Atlantic slope from Campeche to Honduras but is only grown in southwestern Guatemala between 300 and 1 000 m on the Pacific slope. In this area, which is called the Bocacosta and has very fertile volcanic soils, there is a short dry season and an annual rainfall of around 4 000 mm. The plant fruits between late December and April, with a maximum yield around the beginning of February.

Genetic diversity

The most visible characteristic of variability is in the fruit's surface. The areoles are generally marked by raised edges which form a hexagon. In some varieties, the edges are reduced to a criss-cross of brown lines on a smooth, green surface; in other varieties, there is a central prominence on each areole; in some varieties there are well-developed edges and prominences, while still others have an irregular, corrugated surface. The fruit also seems to vary in the thickness of its skin, which is on average 3 mm, but slightly thicker and tougher in the smooth-skinned varieties. The Pacific varieties are green or green with brown spots, while those from the Atlantic side have a thicker, reddish green skin.

No cultivars are known to be established by vegetative propagation. Genetic erosion is evident, since it is a crop with a restricted area in a highly populated region where land is required for building or cultivating coffee. Trees which were sown on coffee plantations have been destroyed or deformed because they produce too much shade or because they were damaged by children picking their fruit.

Genetic erosion is very pronounced in *A. scleroderma*; there are no gene banks and a few plants have been introduced into Australia and the United States (Florida). For this reason, material urgently needs to be collected in southwestern Guatemala (from San Felipe, San Andrés Villa Seca, San Sebastián, Colomba, El Tumbador, etc.).

Cultivation practices

Fresh seeds take about a month to germinate, whether they are collected and dried on the same day or stored in bags for a week or two. They do not need to be soaked or treated in any other way. Seeds that have been stored for two to three months need about six months to germinate. In Australia, *A. scleroderma* grows well when grafted on to stocks of *A. muricata* and *Rollinia mucosa*. When grafted material is planted, it must be borne in mind that the trees should be pruned so that a wide crown remains to facilitate fruit harvesting. This also reduces exposure to wind and bird damage.

The shade requirements of young plants – shade seems to promote growth – need to be studied. However, trees located in sunny positions would have a lower, more compact habit. Trees grown from seed begin to produce at around four years when they reach a height of 4 to 6 m.

Prospects for improvement

The advantages of *A. scleroderma* as a fruit for local consumption and export are its high productivity and the fact that the flavour and aroma of its flesh are not as strong as in other *Annona* species, but are different and pleasant. The abundant, cream-coloured or creamy grey flesh separates easily from the seeds and it does not have sandy grains or fibres that adhere to the seed membrane. The thick, leathery skin does not split and is very resistant to insect attack and ordinary packaging and transport.

Activities that merit close attention regarding *A. scleroderma* are:

- the collection and evaluation of genetic material;
- propagation through grafting on to stock of the same species or related species to obtain low trees with an open crown, which facilitate fruit harvesting;
- running small market gardens or interplanted crops;
- marketing, since it is a "new" fruit even for Guatemalan markets;
- packaging and transport technology to prolong the good condition of the fruit and its acceptance on the market.

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Grain amaranths (*Amaranthus* spp.)

Amaranthus cruentus, Amaranthus hypochondriacus

Botanical names*: Amaranthus cruentus* L., *Amaranthus hypochondriacus* L.

Family*:* Amaranthaceae

Common names*. English:* prince's feather; *Spanish:* huautli, alegría (Mexico), bledos (Mexico, Guatemala), amaranto

Within the great genetic diversity existing in Mesoamerica, which is the centre of origin and dispersion of numerous species, amaranths occupy a leading position. They constituted one of the five essential plants in the basic diet of the pre-Hispanic Mesoamerican civilizations and were an essential part of Aztec tributes.

It is difficult to classify the amaranth into just one of the three main groups of plant foods normally recognized by nutrition specialists: *i*) cereals and tubers rich in carbohydrates; *ii*) legumes and other sources of plant protein; *iii*) fruit and vegetables rich in iron and vitamins, especially A and C. In fact, amaranths belong to all three since, in addition to their leaves being used as a vegetable, the chief interest in their cultivation and use lies in their seeds which, as well as carbohydrates, contain between 12 and 16 percent proteins, with a high lysine content.

Archaeological findings in Tehuacán in Puebla, Mexico, show that they were already cultivated over 6 000 years ago. They reached their maximum use when grown by the Aztecs in the valley of Anáhuac; their cultivation began to fall off in the colonial period, and Huautli was so firmly established in the food, religion and agricultural practices of pre-Cortés Mexico that even a bird which sought its seeds at harvest time was named *uauhtotl*, which comes from "huautli" and the word for bird, *tototl*. A drink (atole) which was prepared with water and huautli or prince's feather flour was called *uauhatolli* and the flour dough filled with its leaf was called *huauquillamalmaliztli* (a dish of bledos [prince's feather] tamales). Its cultivation practices also had a special nomenclature: *uauhteca* was the sowing of its seeds, *uauhpuztequemi* was the name of its harvest and the unshelled seed was called *uauhtlipolocayo*. In the Aztec religion, months were designated in which a dough called *tzoalli* was prepared with the flour of prince's feather seeds and the honey of maguey. Depending on the monthly festivity involved, the dough was used to mould different figures ranging from small pyramids to images of mountain deities. These idols were handed around in pieces among those present and were thus eaten. In the eyes of the colonizers, ceremonies of this type seemed similar to the Christian Eucharist, hence its cultivation was persecuted and its consumption prohibited.

There were actually several factors which acted synergistically to reduce the cultivation of prince's feather; mainly its replacement by other species of grain, introduced from the Old World,

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a lack of appreciation or distaste on account of its flavour, and religious reasons.

The first two reasons were easily substantiated, but demonstration of the third was not so evident because of the tenuousness of its origin. However, sufficient evidence of this cause can be found in the work of chroniclers, especially the religious ones. There are constant references to the diabolical nature of amaranth. The two direct allusions to the prohibition of its cultivation were made by Fray Bernardino de Sahagún in 1570 and by Ruiz de Alarcón in 1626.

Sahagún writes in the *Historia general de las cosas de la Nueva España*, at the end of the First Book which deals with the gods worshipped by the Aztecs: " ...if you know of anything among these natives relating to this subject of idolatry, immediately inform the temporal or spiritual authorities so that it may be quickly remedied.... Anyone who does not persecute this sin and its perpetrators by legitimate and meritorious means shall not be considered a good Christian.... The text of the Holy Scripture gives sufficient proof of the deeply malign nature of idolatry and idolaters.... Another folly greater than the demons [their gods] which they worshipped was that they considered the "cloudy mountains" as gods, made images, called *Tapictoton*, from *tzoalli*. They gave them a human form, painted them various colours, and, when the celebration was over, they shared the images out among themselves and ate them...".

A little further on, Sahagún describes the feast of the god of fire, Xiuhtecutli, on whose image they placed all the vestments of the chief lord and, placing a throne on his altar and beheading many quails in his presence, "poured their blood before him and also offered a cup [incense] up to him as if to a god and offered him small pastries, known as *quimaltemalli* and made from bledos (prince's feather) which were eaten in his honour. In all quarters and in every house before they ate them they offered them fire, before which point they did not eat them...". Also at the end of the ceremony in worship of the god of war Huitzilopochtli, as an act of collective purification, the people of the great Tenochtitlán (today Mexico City) shared out and ate tiny portions of *tzoalli* dough which represented his body. This cult was called *tecuelo* (god eaten).

As can be seen, some rites of the polytheist religion of the ancient Mexicans had a great similarity with the Christian Eucharist.

In 1626, Ruiz de Alarcón mentions the rebellion which was still going on at that time among some indigenous groups against the acceptance of Christianity, and the continuance of idolatrous ceremonies, including the construction of gods with *tzoalli*. Religious persecution of the consumption and, therefore, of the cultivation of this species also prevailed, as shown by the following excerpt from Chapter III of the *Tratado de las supersticiones y costumbres gentilicas que hoy vive entre los indios naturales desta Nueva España*,[1] by Alarcón:

"It is idolatry when as a gesture of thanks that it has ripened, from the first [fruit] they pick, well ground and kneaded, they make idols of a human figure about a quarter of a yard[2] in size; they have much of their wine prepared ready for the day when they make the idols and, having made and baked them, they place them in their oratories as if they were placing an image, and also set a candle and incense there. Among their select groups some of the wine is offered for the dedication... and, seated in a circle before these idols, with much applause begin honouring and praising them... and, as a token of sacrifice, pour the

[1] Treatise on the gentile superstitions and customs which exist today among the Indian peoples of this New Spain. (trans.)

[2] Here, a Latin American yard (*vara*), measuring 0.836 m, or 2.8 ft. (trans.)

FIGURE 8

Grain amaranths: A) *Amaranthus cruentus*; A1) fruit and bracts; B) *A. hypochondriacus*; B1) fruit and bracts

wine..., some or all of it, before the small idols of prince's feather, an action they call *Tlatotoya-hua*.... However, the owners of the small idols guard them carefully for the next day when those who attended the feast and at the oratory divide the idols into pieces as if for votive offerings and consume them all together.... This fact is ample proof of the very great yearnings and efforts of the devil in continuation of his first sin, which was the origin of his arrogance in wanting to be similar to our Lord God... since, in what I have just related, one sees coveted and imitated so realistically the very singular mystery of the Most Holy Sacrament of the Altar, in which Our Lord, summing together the benefits of our redemption, ordered that we should actually eat him, while the devil, who is the enemy of everything good, enjoins that these unfortunates should eat him or allow themselves to take possession of him by eating him in those small idols."

At the famous ceremonial centre of Monte Albán in Oaxaca, when tomb seven was uncovered a single relic was found: a human skull covered with a mosaic of turquoises. Initially, it was thought that the base used for its inlay was a resin, but later it was found that the amalgam was *tzoalli* which, in addition to its sculptural function, was used to perform another religious and purifying function.

As well as the Nahua culture, many others made prince's feather their ritual food in offerings or in confirmation of their gods, such as the Tepehuans, Mayas, Tarahumaras and Yaquis. The Coras call it *bé-be* and the Huicholes *wa-ve*. The Huicholes and the Purepechas manufactured biscuits in the form of animals which the latter called *tuycen*.

The method of preparing *tzoalli* or *tzoale*, that is the mixture of prince's feather flour with maguey honey, is the origin of the present-day manner of preparing *alegría*, a delicacy that has been sold at fairs, in sweetshops and in the streets of Mexico for about the last two centuries. The change that was introduced so as to discourage the use of *tzoalli* was the replacement of the huautli or prince's feather flour with burst seed, which also formed a paste with honey. The method of preparing the delicacy is simple: the seed is burst by heating it and adding to it sugar-cane syrup; the mixture is put into moulds measuring $80 \times 50 \times 4$ cm, pressed down and cut into blocks. Cylindrical biscuits are also made. Sometimes the sweet is packed into plastic bags which allows it to be stored hygienically and kept in good condition for several months.

Although preparation of the *alegría* sweetmeat is the main use of amaranth, in some regions it is used to a lesser extent to make atole, pinole or toasted meal, tamales, *chuales*,[3] dessert and ice-creams and sorbets. It is also added to a mixture of flour to make pastries and pancakes, while the young leaves are used in soups. There are certain foods in which amaranth could be incorporated; for instance atole, milk or bread which are normally served with school meals. This would be a quick way of extending its use. It could also be incorporated in maize tortillas, which are widely consumed in Mesoamerica, or mixed with other flours to enrich their protein content. The possibilities for agro-industrial development with this crop are very promising, since amaranth is very versatile in its use, whether it be in the form of flour, noodles for soup or confectionery, for the extraction of lysine and tryptophan or as a cereal. To this end, agronomic research and machinery are required to achieve industrial development and utilization of huautli or prince's feather which are comparable to those of maize.

The seeds of prince's feather are used for flour

[3]From the Nahuatl *tzohualli*, the ritual paste made by the Aztecs from amaranth seeds; it is a kind of tamale eaten around Mexico City on religious feast days.

(to make tortillas, pinole or toasted meal, confectionery, pastries, biscuits, atoles, "*agua fresca*", small savoury pancakes, desserts, bread, *acalgamas* and breadcrumbs), toasted and burst (in the sweet *alegría*, cereals and preserves) and to extract squalene oil (to manufacture cosmetics).

The leaves are eaten in soups, broths and as a vegetable, and are used in protein extracts, colourings and laxatives. The inflorescences are used for decoration and the stems as animal feed and fuel.

At present, the main areas of cultivation in Mexico are in the states of Guerrero, México, Michoacán, Morelos, Tlaxcala, Puebla and Oaxaca. It is predominantly *A. hypochondriacus* which is sown under heavy rainfall conditions in small areas, with mixed seed of different varieties, as is done with maize, in order to ensure a harvest. In Guatemala, *A. cruentus* is mainly sown, under similar cultivation conditions, in the Departments of Guatemala, Chimaltenango and Alta Verapaz. In recent years, great progress has been made in Mexico in the industrialization of amaranth grain, which is packaged in various forms for human consumption. It is also used as starch in the pharmaceutical industry. In Guatemala, INCAP publishes the journal *El Amaranto* which deals with the agricultural and nutritional aspects of this plant.

As a result of the growing world interest in this crop, the First World Amaranth Congress was held in Oaxtepec in the state of Morelos, Mexico, in September 1991. It was attended by specialists from Argentina, Bolivia, China, Cuba, Ecuador, Guatemala, India, Japan, Kenya, Mexico, Peru, the United States and Venezuela. At the congress, the latest advances in cultivation and use were explained and an international network of amaranth specialists was created.

Botanical description

Amaranths are annuals which grow up to 3.5 m in height and have elliptical to ovate-oblong and lanceolate leaves with an acute to acuminate apex. In *A. hypochondriacus*, the inflorescences are very big and branching, uniform in colour, green or red, and have many flowers with acute bracts, which are rough to the touch. In *A. cruentus*, the plants are smaller, up to 180 cm, with green or red inflorescences which are sometimes spotted and smooth as the bracts are not pointed. The seeds vary greatly in colour. The inflorescences vary in colour and development, with more of a tendency to be erect in *A. hypochondriacus* and somewhat more pendulous in *A. cruentus*.

Germination is epigeal: the seedlings emerge three to four days after sowing and, at 2.5 months, the panicle begins to appear and later flowering occurs. The seeds do not have dormancy problems and maintain their viability at ambient temperature for more than five years, provided their humidity is less than 5 percent.

If there are dormancy mechanisms in the seed, they occur mainly in the wild species. Amaranth has defence mechanisms against diseases: its spiny panicles and seeds, which have a thick, pruinous testa, allow germination in later years.

Ecology and phytogeography

The species of *Amaranthus* cultivated in Mesoamerica are located mainly between 1 000 and 1 500 m. The amaranth develops best in soils with a loamy or loamy-sandy texture and generally does not tolerate clayey soils, since they absorb too much humidity. In areas with a subtropical climate, it is possible to obtain two harvests per year, particularly in irrigated fields.

In temperate zones with an average annual precipitation of 500 to 800 mm, the cultivated areas are for the most part flooded when the rainstorms begin in May and June. Grain yields range from 800 to 1 200 kg per hectare, although it is possible to boost them by increasing population densities and using fertilizers. In experiments in Durango, Mexico, averages of 1 500 to 3 000 kg per hectare of grain have been obtained, using auxiliary irrigation when sowing begins.

Genetic diversity

A. hypochondriacus varies widely, as indigenous cultivars can be found which have red, green or pink ears; the seed may be cream, white, golden or black. The leaf colouring matches that of the ears; however, there are different tones on the stem. Crossings between cultivars of *A. hypochondriacus* are viable, although they are self-fertile: the same is the case with *A. cruentus*. In this species, different ear colours are found: red, green, orange, pink and two-colour (red and green). The colouring of the leaves and petioles matches that of the ear and in some cases the stem has a similar colour; the seed may be white, translucent cream or golden. Interspecific crossings have proved viable, which suggests that coincidence in flowering may produce hybrids.

Until now there have been only a few improved varieties of amaranth in Mesoamerica. In Mexico, INIFAP-CIFAP obtained the variety Revancha, which is grown in the high valleys. The CIIDIR-IPN, Unidad de Durango, has obtained five selections of *A. cruentus* and three of *A. hypochondriacus*, with different characteristics and cultivation cycles.

The use of new cultivation areas and the introduction of more profitable crops, as well as areas devoted to stockfarming, are causing genetic erosion. Germplasm therefore needs to be collected in the main production areas, particularly from native cultivars which might no longer be cultivated. The establishment of gene banks is a task requiring swift action, and INIFAP and the UACH are applying themselves to this. More institutions urgently need to act together with this end in view.

In 1984, under the programme of the CIIDIR-IPN, Unidad de Durango, a series of agronomic germplasm evaluation and genetic improvement trials of indigenous cultivars for the semi-arid regions began; in the future, it is proposed that a gene bank should be set up. The search areas will have to cover the Mexican high plateau: Chihuahua, Sonora, Durango, Sinaloa, which are regions still little explored, and the states of the centre and south which have not yet been completely explored.

Cultivation practices

The amaranth is grown in two ways: in seed beds in the *chinampas* area (central Mexico) and by direct sowing.

Seed bed. In the fourteenth to sixteenth centuries, huautli or prince's feather was grown in the valley of Mexico in *chinampas*, which are "floating gardens" of earth piled on floating mats of twigs in canals and lagoons. The agricultural practices which were used in those times still continue in some localities close to Lake Xochimilco (Tulyehualco, Tláhuac, Mixquic). They consist of preparing seed beds which are later planted out. The following steps are involved:

Building ridges. The ridges may measure from 11 to 20 m in length by 1.5 m wide, depending on the number of plants; the difference in level in relation to the *chinampa* is 10 cm.

Furrow or seed bed. The ridge is covered with mud taken from the bottom of the water surrounding the *chinampa*, until it reaches the level of the soil, i.e. a thickness of 10 cm. This mud, which is the agricultural element of the *chinampa*, is very rich in organic matter, since all the micro- and macro-organic residues of the lake and its surroundings are deposited there.

Once the mud has been removed and placed on the ridges, the excess water is allowed to evaporate ("drain out") through exposure to the sun. When a suitable consistency is reached, it is cut lengthways and breadthways, forming small

4 × 4 cm squares (*chapines*), or occasionally *tepehuales*, in other words larger 20 × 20 cm squares which may include up to five *chapines*.

Sowing. Using a corncob or a finger, a hole is made 1 cm deep in the *chapines*. In each hole six to eight seeds are placed. The *chapín* or seed bed is covered with dried horse manure which is preferred because it is the lightest.

Uncovering the seed bed. On the third day of seed germination, when the seedling reaches 3 to 9 mm, the seed bed is uncovered so that the plantlet may grow without restraints.

Creation of acomanas. When the seed bed has been uncovered, the plantlets are left there for a month to grow approximately 5 to 10 cm. During this time, they begin to be separated from the soil and from one another. *Acomanas* are formed so that the plants do not take root in the ridge and their growth is temporarily arrested, giving time for the rainstorms to arrive (June-September).

Packing. Depending on when the rains begin, the *chapines* are placed in a wooden carrying crate made from pieces of light wood to prevent the plantlets being knocked about or broken during transportation to the cultivation plot.

Transplanting. This a task requiring at least four people. One ploughs the ground so that the damp soil is turned face down while another loosens the seedlings to leave two or three per *chapín*. The *chapines* are laid out on a maguey leaf one end of which is tied at the belt and the other is held in one hand, or else a portable crate is hung from the shoulder, while a third person, dropping a plant every 60 or 80 cm, lowers a *chapín* into the bottom of the furrow; a fourth person arranges the *chapín* in such a way that the plant stays erect pressing the soil down around it by hand or foot, thus completing the transplanting operation.

Threshing. The plants are cut 10 or 20 cm from the soil surface, forming sheaves of ten to 15 plants which are left to dry for a couple of weeks. Threshing starts with armfuls of the dried plant being strewn on to sackcloth stretched over the ground so as to perform the traditional "dance", which consists of trampling the ears over and over again until the seeds work loose. Those that are not separated undergo a further process: the ears are beaten more forcefully with a rope.

Seed cleaning. A sieve is made with a cord sack which is tied by its corners to four tree trunks. One person pours bowls of seed on to it while another moves them around with one hand so that they fall through the openings of the sack. At the same time, the first person fans them with a hat so that the air finishes off cleaning them.

Nowadays, these ancestral practices are accompanied by others, such as fertilizing and threshing, which are no longer done manually.

Storage. The oldest known way of keeping prince's feather is by storage in underground deposits. Large earthenware pots (*cuexcomates*) were also used (2.5 × 2.5 m, with sides 10 to 12 cm thick). Other means used were barns, granaries or crates. These means of storage are still used nowadays but, more frequently, bags of around 50 kg are ensiled or concrete rooms with mud floors which prevent humidity from passing through are built. However, prince's feather seeds can be stored for more than ten years in dry, well-ventilated places.

Direct sowing. In Tlaxcala, Puebla, Oaxaca, Morelos and Guerrero, it is more common to sow an abundant quantity of seed directly into the ridge of the furrow at the start of the rains. Later, the plants are thinned out, which is easier to do when they are 10 to 15 cm high. In general, cultivation practices are similar to those used to grow maize: earthing up, fertilization in two stages and weeding.

Harvesting in these cultivation areas is similar to that in the Mexico valley. During September and October, the ears are cut and, when dried, all the leaves of the stem are piled up so that they can be beaten to remove the seeds, which are then sieved and cleaned. The yields obtained generally range between 800 and 1 500 kg per hectare.

Prospects for improvement

In Mesoamerica, research needs to be done on both the basic aspects of this cultivation and the development of farming technologies for the areas currently in production as well as the areas of future expansion (semi-arid zones of northern Mexico). Local consumption and exports will also need to be promoted. Also essential is a complete programme of basic research, the development of techniques and improved materials as well as advertising campaigns recommending the product and its value as a food. Peru, where a programme of this kind has enabled yields to be increased from 1 800 to 3 000 kg per hectare, and even 6 000 kg per hectare on trial plots, should serve as an example. Complementary extension work has been devoted to the different ways in which the product can be consumed and packaged for export.

Among the projects that could be developed for improving amaranth production in Mesoamerica, the following may be considered:

- the formation of gene banks in the present areas of cultivation (central and northern Mexico, the highlands of Guatemala) to characterize and evaluate native cultivars as well as to make a preliminary selection;
- studies on the adaptation of cultivars to new conditions, especially to mechanized sowing and harvesting;
- the development of new cultivation practices: sowing distance, fertilization, weed control, pest and disease management;
- the development of machinery for rainstorm and irrigation conditions;
- genetic improvement of native material and material introduced from other areas in which the two native species are grown, and of *A. caudatus*;
- an information campaign drawing attention to the nutritional value of amaranth and new forms of use;
- studies on handling the harvested product, its packaging, processing and marketing.

There will have to be an economic and social element in applied research so that experimental results can be evaluated. From the social point of view, a contribution towards improving the peasant diet must be sought in the intensive cultivation of the amaranth, as was attempted some years ago in Guatemala.

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Sapote (*Pouteria sapota*)

Botanical name: *Pouteria sapota* (Jacq.) H. Moore & Stearn
Family: Sapotaceae
Common names. *English:* sapote, mammee zapote, marmalade plum; *Spanish:* zapote, mamey zapoteo, mamey colorado, zapota grande; *French:* grosse sapote

The sapote (*Pouteria sapota*), which originates from the lower parts of Central America, is a fruit-tree with free pollination, which generally multiplies by seed. Its fruit may be eaten raw or green and the flesh is used to make jams, ice-creams and sauces; when cooked, it can be an acceptable substitute for apple purée and may also be used in confectionery.

Chemical analysis shows that 100 g of sapote flesh contains 65.6 percent water, 1.7 g of protein, 0.4 g of fat, 31.1 g of carbohydrates, 2 g of fibre, 1.2 g of ash, 40 mg of calcium, 28 mg of phosphorus, 1 mg of iron, 115 mg of vitamin A, 0.01 mg of thiamine, 0.02 mg of riboflavin, 2 mg of niacin and 22 mg of ascorbic acid.

Cultivation of this species still cannot meet the demand of the external market and may play an important role as a source of revenue and in helping to make up an adequate diet, particularly for low-income urban and rural populations.

In some parts of Mesoamerica, ground sapote seeds are used to give chocolate a bitter flavour and characteristic aroma; in Costa Rica, they have been used as a linen starch. In Guatemala and El Salvador, the oil from the seed is used as a skin tonic, to prevent baldness, to reduce muscular pain and to treat rheumatic ailments.

This tree produces latex, which is used as a caustic to remove fungus from skin. Sapote wood, which is strong and solid, can be used to make furniture and other objects that require stout wood.

From the ecological point of view, promoting the cultivation of this species is of enormous importance since it can help maintain genetic diversity and prevent some genotypes of potential value from disappearing. The establishment of this species as a crop in traditional production systems will make it possible to maintain highly sustainable fruit-growing development. Agro-industrial development will benefit from the production of fruit of great nutritional value and by-products of high value added.

Botanical description

The sapote tree can attain a height of 20 to 25 m; its crown is generally symmetrical or irregular, with thick branches and dense foliage. The leaves are ovate or lanceolate and are concentrated on the apex of the branches. The flowers are small, almost sessile, and grow in profusion under new branches and along leafless branches. Each flower consists of five true and five false stamens; the pistil has only one stigma and the ovary has five carpels.

The fruit ranges in shape from fusiform, elongated, ellipsoid to spherical, and may weigh up

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to 3 kg in some genotypes. The skin is hard, rough and brittle, and is of a dull, reddish colour. The flesh varies in texture and is red, orange or greyish in colour; it is aromatic, sweet and soft when ripe; and usually has some fibres, depending on the cultivar. In general, the fruit contains one or more seeds. These are large with sharp ends and ellipsoid in shape, dark brown in colour, smooth and shiny on the dorsal segment and cinnamon-coloured on the ventral part. The seeds take between 40 and 70 days to germinate, a process that can be speeded up by simply removing or scarifying the husk before sowing.

Ecology and phytogeography

Very little has been written on the climatic conditions, pests, diseases and other factors limiting the production and productivity of the sapote. However, the most important factors from an ecological point of view are height, soil, temperature and rainfall, since they can limit the cultivation area, and to a great extent, may be considered the most critical factors for its development. In some places, wind may be the most important limiting factor. The ease with which some diseases and insects can spread depends on relative humidity.

The sapote adapts well from sea level up to 1 400 m. It grows in the heavy clays of Puerto Rico, the sandy clays of Guatemala and even in the sandy soils of Florida in the United States.

The essential characteristics of the soil for optimum cultivation are the quality of drainage, depth, degree of acidity, fertility, adequate groundwater level and moderate permeability. In tropical areas, there are many soils with these characteristics. However, soil factors are inseparably linked to the sapote plant's photosynthetic potential, for which reason the low fertility of some tropical soils limits the yield of this species.

The sapote does not tolerate low temperatures, even if of short duration. Depending on its locality, the sapote can be profitable if sown in areas where the temperature does not fall below 15°C. Extreme temperatures can temporarily affect some of the functions of any of the tree's organs. In regions where the sapote grows best, the average temperature ranges between 25 and 28°C. On some commercial plantations, such as in Léon in Nicaragua, good yields and fruit quality are obtained at temperatures between 30 and 33°C.

The amount of rainfall needed for growing the sapote ranges between 800 and 2 500 mm; how much rainfall there is will depend on the type of growing area.

If the dry season is prolonged in a given area, harvesting may be concentrated in short periods while, in places where there is no dry season, the crop can be harvested with maximum fruiting throughout the year.

Genetic diversity

The word "sapote" (or "zapote") comes from the Aztec "tzapotl", a collective name which applies to several species of sweet, spherical fruits with large seeds. The Sapotaceae family includes other close species of great value, such as the sapodilla (*Manilkara zapota*), star apple or caimito (*Chrysophyllum cainito*), canistel (*Pouteria campechiana*), pan de vida (*P. hypoglauca*), lúcumo (*P. obovata*) and caimo (*P. caimito*).

In the most recent taxonomic classification, sapotes comprise three species: *Pouteria sapota*, *P. viridis* and *P. fossicola*, although it is accepted that there are intermediate groups between the three (Pennington, 1990). Despite morphological differences and sometimes differences in geographical distribution, if compared with other fruit-tree species, the value of these three taxa would be at variety level.

In Florida, several cultivars of the sapote are currently grown, of which brief descriptions have

FIGURE 9

Sapote (*Pouteria sapota*): details of a cross-section and shapes of the fruit

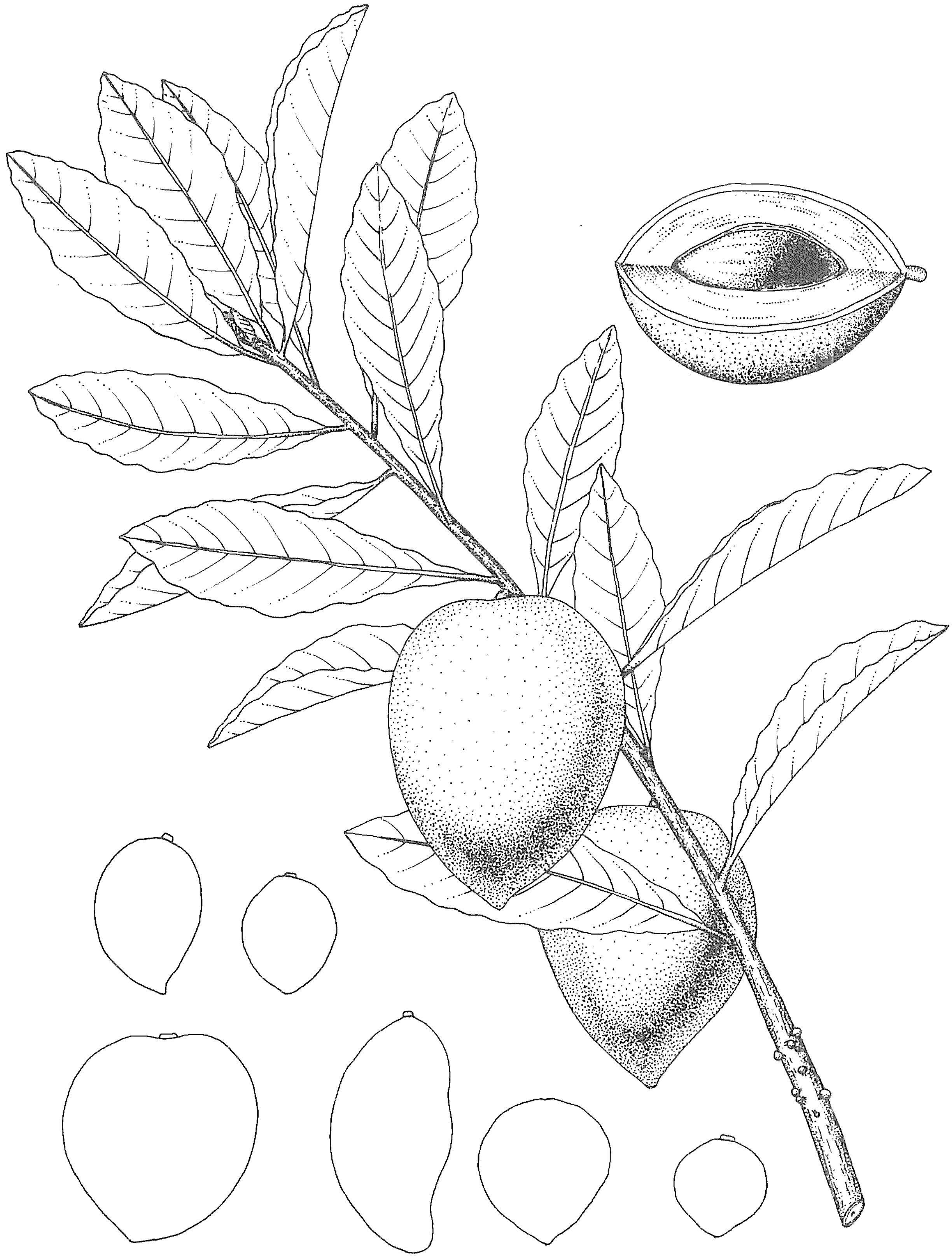

TABLE 4 Characteristics of the best sapote cultivars in Florida, 1991

Cultivar	Harvest	Weight (g)	Flesh colour	Flavour	Yield
Abuela	October-November	740 - 2 400	Red	Excellent	Regular
Area No. 3	July-September	400 - 740	Pink	Good	Regular
Chenox	May-June	400 - 850	Pink	Good	Regular
Copan	July-August	425 - 900	Red	Excellent	High
Flores	November-December	740 - 2 400	Red	Excellent	High
Florida	March-April	400 - 1 130	Reddish	Good	High
Francisco Fernandèz	August-September	560 - 700	Reddish	Excellent	Regular
Lara	August-September	400 - 1 130	Reddish	Excellent	High
Magaña	April-May	740 - 2 400	Pink	Good	High
Mayapân	July-August	510 - 1 135	Red	Good	High
Navidad	December	400 - 740	Salmon	Excellent	High
Pace	March-April	425 - 900	Salmon	Excellent	High
Patín	July-August	400 - 1 130	Reddish	Excellent	Regular
Piloto	August-September	400 - 7 40l	Reddish	Excellent	Regular
Tazumar[1]	January-February	400 - 850	Pink	Good	High
Viejo	December	400 - 500	Red	Excellent	High

[1] This cultivar has a second harvest between July and August.

been made (Campbell and Lara, 1982). Table 4 indicates the 16 best cultivars.

Much of the genetic variability of the genus *Pouteria* is found in the tropical forest areas which are still unexplored. These regions are not very accessible and, in some cases, guerilla groups in the mountains make it difficult to collect genotypes which may be undergoing genetic erosion through abandonment. Furthermore, urban development is accelerating the loss of genetic diversity of this and other species. It is surprising to note how trees of great value are being felled daily to make way for buildings and other constructions on the best soils with a high agricultural potential.

The Indians, on the other hand, leave sapote trees when clearing the forest and, in Guatemala, they are frequently found on land which has long since been given over to maize.

The protection of genetic resources, including the Sapotaceae family, is an international responsibility. The costs and benefits of this protection should be shared out equitably. In general, many of the countries with a great genetic diversity are developing countries, hence they are unable to defray the costs of *in situ* protection of genetic resources on their own. An international mechanism is therefore needed to meet the costs this responsibility entails. Such financial support should be used in particular for taking care of populations of endemic species in each ecological region and in zones of exceptional diversity, particularly the lowland forests, tropical and subtropical rain forests as well as isolated mountains and other places where wild species with a high genetic value still exist.

The intensification of agriculture has caused a reduction in the genetic variability of this tropical species by replacing wild cultivars of sapote with other exotic species.

Cultivation practices

In general, Sapotaceae have been propagated by seed. There are few commercial plantations. Fruit for everyday consumption comes from solitary trees which grow close to people's homes or are interspersed with other perennial crops such as cocoa and coffee.

Until a few years ago this species took seven to eight years to come into production, since sexual propagation by seed was used. This created a wide variation in populations, greatly reducing the possibility of harvesting genotypes that were uniform in size, weight and quality.

At present, the vegetative methods of propagating sapote involve grafting, a system which improves productivity characteristics and halves the period between sowing and harvesting. In this way, incompatibility problems between stock and graft are corrected and the desirable characteristics of grafting are combined with the special qualities of the stock.

Before grafting, there must be a good selection of stocks. Grafting must be done at a time when the stock and scion are in the appropriate physiological state to allow a greater percentage of takes. The preferred grafting methods are side grafting and cleft grafting. The optimum state for selecting vegetative material (scions) is when the tree is dormant, i.e. when the plant sheds all its leaves; this generally occurs during the summer. To select scions during the winter, the shoots need to be ringed eight to ten days before grafting. The stocks must be approximately 1 m high, 1.2 cm thick and nine months old. It should be borne in mind that the cuts in both the stock and the scion have to be made in the most uniform area of both barks so that the join is complete. Once the operation is completed, the graft is tied with special tape and a little melted paraffin wax is applied for protection.

A week later, the apical part of the stock is cut, leaving 30 cm between the shoot and the graft. This step is repeated after two weeks when only the graft is left. At approximately two months, the part of the plant which has joined to the stock begins to bud. At four months, the tape is removed in order to let the new shoot develop freely and, two months later, the plants can be planted out in the field.

Present cultivation situation. Central America is going through a difficult economic situation, and this is reflected in the agro-industrial sector. An economic recovery is needed that involves investments in non-traditional products. The sapote may be quoted as an example of a non-traditional species which offers economic potential for agricultural diversification in the region and hence for achieving a better ecological balance. In Central America, South America and the Antilles, interest in this crop is a recent development. There are just a few small commercial plantations and isolated trees on uncultivated land which may allow the crop to be promoted both at a local level and for export.

In these regions, there are no germplasm collections and few skilled technicians for carrying out the technological transfer of cultivation. Furthermore, Central America has climatic, topographical, soil and social characteristics which could allow this genetic resource to be developed and utilized more fully. In spite of its potential benefit for growers and industry, there is still little information and research being done on exploitation and use of the sapote.

A better knowledge of the genetic diversity, seasonal variations in production, quality, supply of and demand for this species would enable its monoculture, or cultivation together with other perennial crops, to be encouraged.

Prospects for improvement

The future of sapote cultivation is linked to the selection of the best genotypes for each country.

Selection criteria will have to be based on the vigour, height and build of the trees, the production, shape and size of the fruit, the quantity of flesh and fibre and the aroma and flavour. The requirements of internal and external markets will need to be studied and the selling prices of specific cultivars compared.

Establishing the sapote may be a slow process and will require research, time and investment. Experience with other crops shows that, without adequate marketing and sustained development strategies, growers may stand to lose. Indeed, they do not usually know the quality standards which apply to production, nor the methods for effective husbandry, and also have to cope with high harvesting costs, low prices paid for the product, small yields and a shrinking market. It should be stressed that research, commercial production and marketing are the key factors for successfully establishing non-traditional crops.

When starting to develop a crop such as the sapote, an evaluation needs to be made to demonstrate its prospects for adoption by growers. Consideration will have to be given to the area of adaptation, the availability of land, bank credit, production costs, market security and probable net income for the grower; these factors will have to be compared with those of other competitive crops. Information will also have to be collected on the availability of outstanding genotypes, stock and graft nursery capabilities and cultivation practices, as applied to the seedling and in the field.

Coordination between production and marketing is essential if a new product is to be presented successfully. If the market is created before production meets demand, buyers may show a lack of interest and the product may lose its acceptability. If production exceeds demand, growers may be disillusioned by the losses and, in some cases, may even change crops.

With regard to the potential areas for a crop's introduction and cultivation, priority should be given to sampling genetic diversity. This stage can take at least two years, depending on the availability of germplasm. For species that are widely dispersed or located in geographically or politically inaccessible areas, collections may continue indefinitely. Permanent collections need to be established while finance must be made available for the preservation of those that already exist.

From the social point of view, it is worth stepping up the propagation of this crop and making its nutritional benefits available to low-income rural populations. From the economic point of view, the export of the dried fruit or flesh would bring enormous advantages to these groups, since it would constitute an inflow of foreign exchange. Ecologically, this species could be combined with other perennial crops such as cocoa and coffee, thereby providing emergency income for the grower should the market price of the main perennial species decrease or fluctuate constantly.

Six stages may be envisaged in research and development:

- exploration for, and collection of, germplasm;
- observation and selection of cultivars for domestic consumption and export;
- chemical studies and use;
- evaluation and agronomic validation;
- production and processing for local consumption and for export;
- marketing.

Experiments on evaluation and agronomic validation must be carried out in various locations and environments and should include cultivation practices, harvesting methods, yield and quality. A high genetic diversity must be maintained so as to select the genotypes suitable for each environment.

To carry out this programme, credit needs to be made available with acceptable rates of interest and repayment terms, while there must also be the political will to ensure implementation and technical support up to the marketing stage.

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Spanish plum, red mombin (*Spondias purpurea*)

Botanical name: *Spondias purpurea* L.
Family: Anacardiaceae
Common names. English: Spanish plum, red mombin; *Nahuatl:* ateyaxocotl; *Spanish:* jocote (Mexico [Oaxaca], Central America), ciruelo (Mexico [Jalisco, Yucatán])

Spondias purpurea was grown widely from Mexico to the northern region of South America when the Europeans arrived, as can be deduced from the descriptions of the first chroniclers (Oviedo, Sahagún). It spread through the Antilles and the rest of South America and was possibly taken from Mexico to the Philippines. The fresh fruit has a very pleasant taste and its consumption is increasing. It is a valuable but economical raw material for the preparation of soft drinks, preserves and syrups and is also eaten as a dried fruit. The current marginalization and scarcity of commercial plantations are largely due to a lack of attention on the part of producers, technical experts and agricultural extension workers, who are concentrating their efforts on other fruit-trees in greater demand on the foreign market.

The most widespread use of *S. purpurea* is as a fresh fruit for local consumption and for supplying city markets. In Mexico and Guatemala, it is used in other forms which are possibly of post-Hispanic origin. In one form, the fruit is boiled in brine for five to ten minutes and then dried in the sun, either on tables with a wire mesh or reeds for three days or on driers on mobile units for ten to 12 hours. By this process, the dried fruit is reduced to one-quarter of its fresh volume. Another way to prepare the fruit is to heat it in unsalted water and dry it in the sun, while a third process, used in Mexico to obtain *ciruelo negro*, consists of pricking the skin of the fruit, placing it in syrup (1 kg of sugar in a bottle of water) and letting it simmer until the sugar burns or becomes concentrated. *Ciruela cristillina* is a fourth method of preparing the fruit, similar to the previous one, only the fruit is gathered while it is ripening and is boiled for a shorter time.

Other uses of *Spondias* pulp include as an atole, mixed with maize flour and sugar, and in the preparation of wine, *chicha* (maize liquor) and soft drinks.

Analyses of the fresh fruit show that the percentage of moisture in the flesh ranges from 76 to 86 percent; it is very low in protein and fat and contains appreciable quantities of calcium, phosphorus, iron and ascorbic acid.

Its consumption is currently increasing throughout Mesoamerica. The bulk of production comes from isolated trees or hedges, while very little comes from well-ordered and maintained plantations, such as the ones seen around the city of Oaxaca. However, it is a very promising fruit-tree because it is accepted on the market; it is a hardy species with a high resistance to drought; it is easy to produce on poor soil; and its propagation is exclusively vegetative, which ensures an early harvest.

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Botanical description

S. purpurea is a small tree, growing 4 to 8 m, with a broad crown, irregular trunk and fragile branches; its leaves are composed of five to 12 pairs of elliptical-acute leaflets, 2 to 4 cm in length and which fall before the flowering period. It has red flowers in 3 to 5 cm panicles, situated along the small branches; the fruit is an irregular oval drupe, somewhat gibbous, smooth and shiny, 4 to 5.5 cm long and a violet to yellow colour, with a woody kernel which contains the seeds. The flesh is sparse, creamy, yellowish and bitter-sweet in the cultivated plants and very acid in the wild plants. It contains malic acid, sugar, calcium malate and starch. The growth cycle has only been studied in Mexico, in Sinaloa and Puebla. In Sinaloa, the trees have foliage from June to October, leaves fall from October to December and the trees are without foliage from January to May. Flowering occurs in February and March and fruiting in June. In Puebla, the trees have leaves from March to October, leaf fall occurs from October to December and the trees remain leafless from January to April. Flowering takes place from December to January and the fruit ripens in April and May. Of great interest is the absence of seed formation in this species, an aspect that was first studied in the Philippines. In the "nut", which occupies the central part of the fruit, only remnants of aborted seeds are found. This is due to both poor pollen formation and the oosphere. Natural distribution is thus completely limited, but the ease with which stems and branches sprout, together with their fragility, allows a very limited natural propagation. Recognition and conservation of the numerous variants which this species displays is possibly due to the action of humans.

Ecology and phytogeography

The natural populations of *S. purpurea* grow from sea level to an altitude of 1 200 m in areas with alternating seasons from Sinaloa and Jalisco in Mexico to Colombia. It is known that *S. purpurea* was taken from Nicaragua to Panama and South America in the form of cuttings with a viability of several weeks. It grows in regions of low humidity and remains leafless during the dry season. It has been introduced into similar tropical regions in Southeast Asia and also in subtropical areas (Florida).

Genetic diversity

Numerous clonal varieties of *S. purpurea* are known, but there has been no formal characterization of them. In Yucatán there are 20 varieties and, although some may be *S. lutea*, this is perhaps the most notable varietal concentration in Mesoamerica. Ak-abal, with small, poor-quality fruit and smooth succulent roots, like those of the Brazilian species *S. tuberosa*, is used for pickles. The cultivated varieties may be divided into two groups:

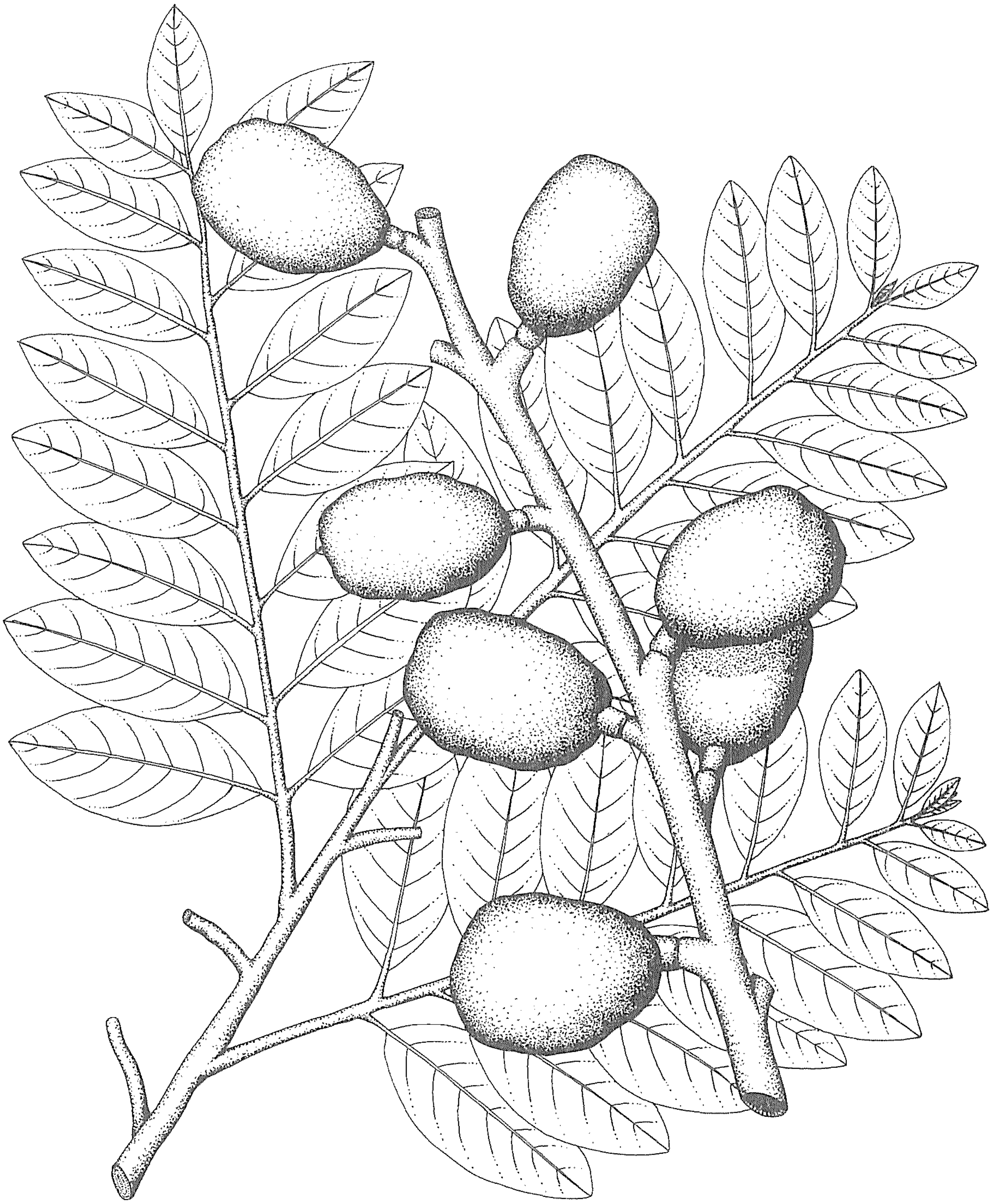
Summer mombin. This fruits (in Central America) during the dry season from February to May, has ellipsoidal fruit that is 2.5 to 3 cm long with smooth, purple-red skin and yellow, smooth, sweet and slightly acid flesh. When green, these varieties look like olives. The varieties Tronador, Criollo, Nica and Morado grow between 0 and 800 m.

Winter mombin. This is of superior quality, with fruit that is 3.5 to 4.5 cm long, red or yellow, smooth or with protuberances, and has firm, sweet, slightly acid flesh. It ripens at the end of the rainy season (September to December). Most of these varieties grow between 800 and 1 200 m and those known include Petapa, Corona and Cabeza de loro.

It has been suggested that these two groups should be considered as different species, but their distinctive characteristics are within the normal varietal range in the cultivated species. Wild populations, such as the iguana mombin in

FIGURE 10

Spanish plum, red mombin (*Spondias purpurea*)



Costa Rica, have very attractive, red or purple fruit, with yellow flesh similar to certain grapes, although it is acidic and astringent. There are other wild varieties in Central America, some with common names. Being a species in which crossings must be very difficult, neither varietal richness nor related species, such as the jobo (*S. lutea*), are of great use in genetic improvement.

On the other hand, the study and evaluation of clonal variation may offer new material. In this connection, regions of particular interest are: the Pacific area of Nicaragua which has been been famous for its mombin or Spanish plum since the days of colonial settlement; Yucatán, where numerous varieties exist; and southwestern Mexico and the neighbouring region of Guatemala. There are no collections of germplasm, but they should not be difficult to establish and maintain. In addition to *S. lutea*, there are two cultivated species: ambarella, Jew's plum or golden or Otatheite apple (*S. dulcis*) from Polynesia, which is grown sporadically in tropical America; and imbu mombin (*S. tuberosa*) from the dry region of northwestern Brazil, whose fruits are of excellent quality. These three species are propagated by seed.

Cultivation practices

Being a vegetatively propagated species, the sowing material consists of straight cuttings, more than 6 cm thick and at least 1.5 m long, with horizontal cuts. They are cut at the start of leaf production which generally coincides with the beginning of the rains. The cuttings are kept in the shade for a couple of weeks and are planted 8 × 8 m apart at a depth of 30 cm. As a rule, the only cultivation practice is pruning of the branches to cause numerous shoots to form along the main branches. Pruning can be done every year, since the flowers bud on the current year's branches. The experience of producers in Mexico is that pruning increases the size and weight of the fruit.

In Oaxaca, there are commercial plantations on which the trees are pruned at a height of 2 m; the cuttings are planted in double, inclined rows, with 3 m between the pairs of rows; when pruned, they look like European apple orchards.

There are no serious pests apart from the Mediterranean fruit fly (*Ceratitis capitata*) and Mexican fruit fly (*Anastrepha ludens*) which cause serious damage.

Harvesting on the pruned trees is an easy operation, performed by shaking the branches with poles or sticks; the fruit is gathered from the ground. Throughout the region where mombin is produced, the green fruit is eaten a great deal, as is the green fruit of the ambarela (*S. dulcis*).

Prospects for improvement

S. purpurea can be grown on marginal land of low agricultural value, on which the tree could be used for reforestation and produce extra profit for growers. Its production season is short, and late or early varieties that extend this period must be sought. Marketing, whether locally or in major towns, does not pose any major problems, as it is a widely accepted product.

The main limitation is attack from fruit flies, since control is expensive and beyond the range of small producers. An evaluation of cultivars that have some degree of resistance would be very advantageous, as would agronomic measures that tend to reduce infection by flies. Another theme to be investigated is the effect of defoliants on the acceleration of fruit formation.

So far, there has not been any industrialization of the fruit. Improving the primitive processes described earlier and research into others, as has been done in Florida with the artificial drying of slices of the flesh, may open up new possibilities for consumption.

Varieties of *S. purpurea* urgently need to be collected in one or more gene banks, which allow a quick evaluation of their genetic characteristics (resistance to insects, production period, response to pruning), and sowing material must be distributed among growers. In areas with sufficient space, it is recommended that *S. purpurea* be planted as a hedge, since its fruit production represents extra profit for the grower.

Finally, transport and packaging problems must be studied to see how they can be improved, since they are at a very primitive stage.

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Tomatillo, husk-tomato (*Physalis philadelphica*)

Botanical name: *Physalis philadelphica* Lam.

Family: Solanaceae

Common names. *English:* tomatillo, husk-tomato, jamberry, ground cherry; *Spanish:* tomate de cáscara, tomate de fresadilla, tomate milpero, tomate verde, tomatillo (Mexico), miltomate (Mexico, Guatemala)

The tomatillo or husk-tomato (*Physalis philadelphica*) is a solanaceous plant cultivated in Mexico and Guatemala and originating from Mesoamerica. Various archaeological findings show that its use in the diet of the Mexican population dates back to pre-Columbian times. Indeed, vestiges of *Physalis* sp. used as food have been found in excavations in the valley of Tehuacán (900 BC-AD 1540). In pre-Hispanic times in Mexico, it was preferred far more than the tomato (*Lycopersicon* sp.). However, this preference has not been maintained, except in the rural environment where, in addition to the persistence of old eating habits, the tomato's greater resistance to rot is still valued. Possibly because of the fruit's colourful appearance and because there are ways of eating it which are independent of the chili (*Capsicum* sp.), the tomato achieved greater acceptance outside Mesoamerica and *Physalis* sp. was marginalized, or its cultivation was discontinued, as happened in Spain. It is relevant to note that only in central Mexico is the fruit of *Lycopersicon* sp. known chiefly as "jitotomate", since in other parts of the country and in Central and South America it is called "tomate".

P. philadelphica was domesticated in Mexico from where it was taken to Europe and other parts of the world; its introduction into Spain has been well documented. Indeed, it is believed that this species originated in central Mexico where, at present, both wild and domesticated populations may be found.

The name "tomato" derives from the Nahuatl "tomatl"; this word is a generic one for globose fruits or berries which have many seeds, watery flesh and which are sometimes enclosed in a membrane.

Of the great number of species of the genus *Physalis*, very few are used for their fruit. *P. peruviana* L. has been grown in Peru since pre-Columbian times. The fruit of *P. chenopodifolia* is picked in the state of Tlaxcala, Mexico. In Europe, *P. alkekengi* is grown as an ornamental plant because of the colourful calyx of its fruit, and its fruit also is used in central and southern Europe.

The tomatillo has been a constant component of the Mexican and Guatemalan diet up to the present day, chiefly in the form of sauces prepared with its fruit and ground chilies to improve the flavour of meals and stimulate the appetite. The tomatillo is also used in sauces with green chili, mainly to lessen its hot flavour. The fruit of

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the tomatillo is used cooked, or even raw, to prepare purees or minced meat dishes which are used as a base for chili sauces known generically as *salsa verde* (green sauce); they can be used to accompany prepared dishes or else be used as ingredients in various stews. An infusion of the husks (calyces) is added to tamale dough to improve its spongy consistency, as well as to that of fritters; it is also used to impart flavour to white rice and to tenderize red meats.

About ten years ago the crop began to be industrialized in Mexico and agro-industries are currently estimated to process 600 tonnes per year, 80 percent of which is exported to the United States as whole tomatillos, without a calyx and canned, while the remainder is used in the preparation of packaged sauces for the domestic market.

P. philadelphica is acquiring importance as an introduced crop in California as a result of the growing popularity of Mexican food in the United States. Furthermore, numerous medicinal properties are attributed to it.

Official statistics show that, in 1984, 15 248 ha were sown in Mexico, with a total production value of 5 797 million pesos and an average per caput consumption of 2.32 kg. Both in Mexico and Guatemala, wild tomato fruit from cultivated fields has a predominant place in the diet, hence in some regions it is an important product among those gathered in rural areas for immediate consumption and for sale.

Botanical description

P. philadelphica is an annual of 15 to 60 cm; it is subglabrous, sometimes with sparse hairs on the stem. The leaf lamina is 9 to 13 × 6 to 10 mm; its apices are acute to slightly acuminate, with irregularly dentate margins and two to six teeth on each side of the main tooth, of 3 to 8 mm. The pedicels are 5 to 10 mm, the calyx has ovate and hirsute lobules measuring 7-13 mm. The corolla is 8 to 32 mm in diameter, yellow and sometimes has faint greenish blue or purple spots. The anthers are blue or greenish blue. The calyx is accrescent, reaching 18 to 53 × 11 to 60 mm in the fruit, and has ten ribs. The fruit is 12 to 60 × 10 to 48 mm in size and sometimes tears the calyx.

Ecology and phytogeography

The *P. philadelphica* plant grows from southern Baja California to Guatemala, from 10 m in Tres Valles, Veracruz, to 2 600 m in the valley of Mexico.

Genetic diversity

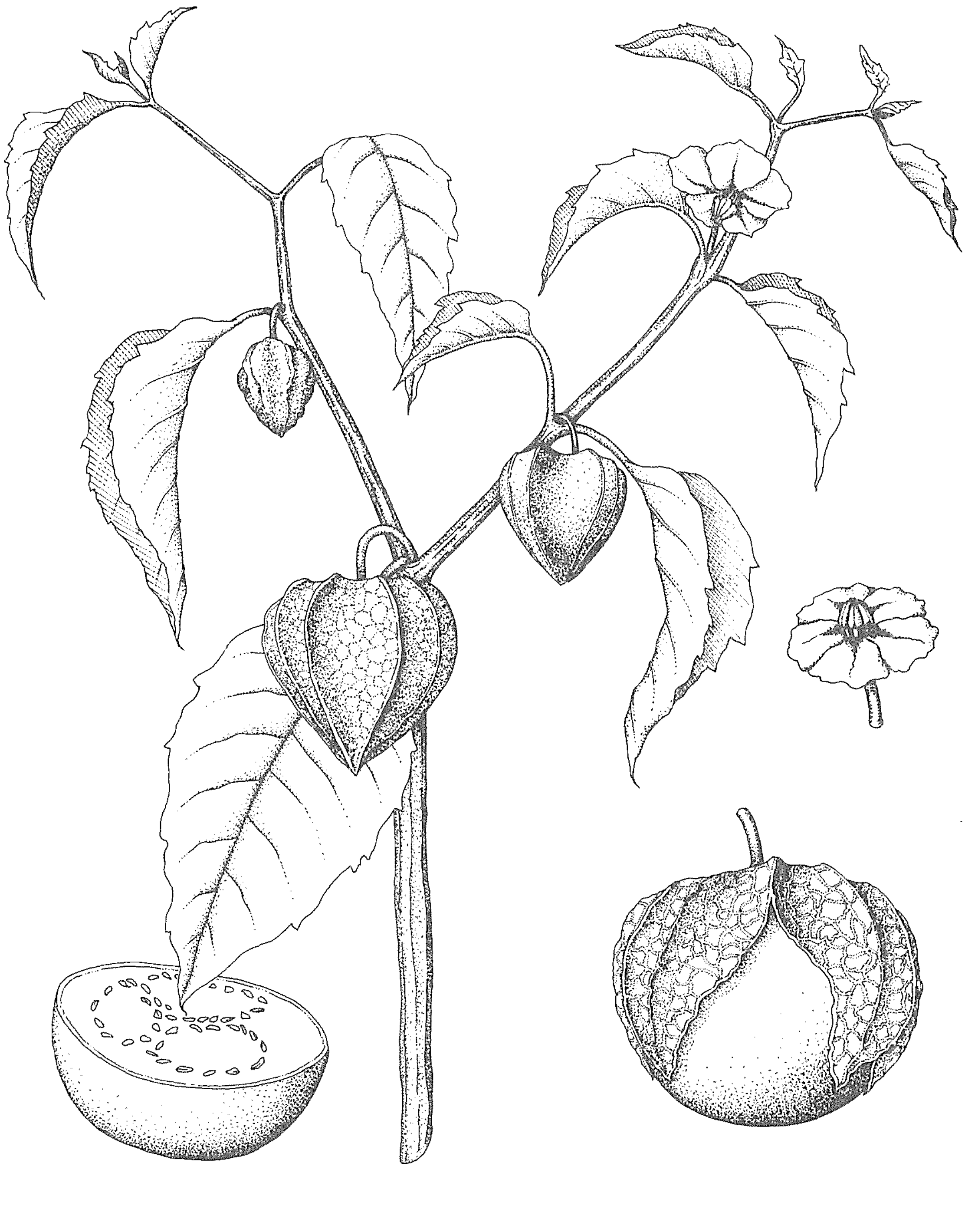
There are many local or indigenous varieties of *P. philadelphica* which producers recognize by fruit colour and size as well as by the plant's growth habit although, within these varieties, there is wide variation, possibly because of their self-incompatibility. The wild forms are very often found growing in cultivated fields in traditional agricultural systems, mainly in combination with maize, beans and gourd. In Mexico, another type of tomato is found which is sold on the markets as wild from cultivated fields. In actual fact, it is a cultivated tomato with a small fruit; the reason for this fraudulence lies in the fact that the price of wild tomatoes growing in cultivated fields is double that of the cultivated tomatoes.

The diameter of the fruit is bigger in the Mexican tomato (1.08 to 4.9 cm) than in the Guatemalan tomato (1.04 to 2.89 cm). However, these measurements correspond mainly to the cultivated tomatoes. In Guatemala, purplish green, yellowish green and purple tomatoes are preferred; in Mexico, on the other hand, the variation in colour is greater, as there are yellow, various shades of green and purple fruits.

The characteristics showing the greatest variation are fruit size, colour and average weight; the

FIGURE 11

Tomatillo, husk-tomato (*Physalis philadelphica*): details of the flower and fruit with an accrescent calyx, and a cross-section of the fruit



number and weight of fruit per plant; the consistency and colour of the flesh; the colour and length of the calyx; flower size; the number and size of the nodes on the first bifurcation of the plant; stem colour; the size and number of teeth per leaf; branching; earliness and pubescence.

The tomatillo or husk-tomato is a vegetable which is used widely and continuously throughout the year; its current situation is as follows:

- wild fruit found growing in cultivated fields is picked and sold;
- small-fruited varieties, similar to those found growing wild in cultivated fields, are specifically grown for the market;
- there are numerous local indigenous selections with a large fruit;
- the Mexican varieties Rendidora and Rendidora mejorada, produced by INIFAP's plant improvers, are rarely used.

In several regions of Mexico the species *P. chenopodifolia* Lam. grows wild in cultivated fields: its use as a potential resource has been recorded.

The species of *Physalis* in Mexico and Guatemala are not in any immediate danger of genetic erosion. However, extensive explorations must be carried out to collect both cultivated material and wild plants found in cultivated fields so as to consolidate the gene banks and contribute material and information towards the genetic improvement programme for this crop.

At present, INIFAP's gene bank in Mexico has approximately 190 collections of *Physalis* species, obtained from four of the country's states while, in the gene bank at the University of San Carlos, there are 41 accessions from several regions of Guatemala.

Cultivation practices

Cultivation practices are common to the majority of the solanaceous plants. Transplanting of the tomato is widespread, principally in the areas where frosts make it essential. Its advantages include saving on seed, reduced weeding and the possibility of starting the cycle while there is still another crop on the ground as well as shortening the growing cycle. Generally speaking, weeding is done by hand or using mechanical implements. Most growers use chemical fertilizers (nitrogen and phosphorus): the doses range from 120 to 240 kg of nitrogen and from 60 to 150 kg of phosphorus per hectare. Given the resources, growers are confident they can control pests and diseases affecting the crop. However, they would need to know more about the doses, appropriateness, products and cost-effectiveness ratios of these control practices.

The tomatillo or husk-tomato is grown mainly on irrigated land. Because of this, sowing dates vary within each producing area, which explains why this tomato is found on the market throughout the year. In some areas it is grown on dry land, both using residual humidity and during the heavy rainstorms. Sowing density ranges from 17 000 to 25 000 plants per hectare. The fruit is harvested when it reaches its normal size, when it has a firm consistency and generally when the apex of the calyx has begun to break. Small-fruited varieties, selected for this purpose, undergo cultivation practices similar to those used for the large tomato.

The greater percentage of dormancy occurs in the seed recently extracted from the fruit. In less than a year it reaches its maximum germination potential, losing it drastically as from the third year under commercial storage conditions.

For marketing purposes, the small fruit must not fill the calycinal envelope. On the other hand, the large tomato must fill it completely and should preferably break it to reveal part of the fruit (this is visually attractive to the purchaser).

The wild tomatillo found in cultivated fields adapts to various environments but it appears mainly on cultivated ground and sometimes care is taken to prevent its removal during weeding and earthing up. It appears most commonly on parts of land where vegetable waste is concentrated and burned after clearance. This tendency may be due to enrichment of the soil with the ash, the effect of which is to stimulate high temperatures in the seeds. Its apparent resistance to the herbicide 2,4-D amine, which is widely used on maize, may help its survival and even its spread (through the reduction of competition in the treated fields) in some agricultural regions.

The only two Mexican improved varieties, Rendidora and Rendidora mejorada, have the following characteristics: a smaller and more uniform habit; few or no hollow fruits; and firmer fruit of a lime-green colour.

Prospects for improvement

The variety Rendidora was formed from the best collections selected in the state of Morelos, where improvement work was carried out. Rendidora mejorada was derived from this variety. In Guatemala, in spite of the wide genetic variation recognized, genetic improvement of this crop is still in its early stages. The characteristics most affected by the environment are leaf size and shape, growth habit and the growing cycle of the plant. Soil fertility stands out as an environmental factor in expression of the phenotype.

Genetic improvement work in Mexico should aim at: plants with large and firm, deep green (not yellow) fruit; high yield, wide adaptation and resistance to viral diseases and powdery mildew (*Oidium* spp.). Improvement aims in Guatemala should be the same, except regarding fruit colour, since purplish green and yellowish green tomatoes are preferred in that country.

P. chenopodifolia is in the initial stage of domestication and shows a favourable response to agricultural practices; accordingly, it must be collected and evaluated so that the potential for better utilization in the future may be established.

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Andean agriculture

Neglected crops of the Andean region

Common to Andean civilizations of the past was the existence of a well-organized agriculture based on an appropriate use of the environment and the continuous improvement of food plants and domesticated animals. These civilizations were aware that agriculture is the source of food and that it guarantees society's stability.

Following this line of thought, the history of major civilizations should be approached from the point of view of the domestication of plants, their variability, the improvement of the main crops and the advances achieved in agriculture.

Numerous publications have dealt with domesticated plants in the Andean region and their importance for regional and world food supplies. However, the factors which caused the marginalization of these crops have rarely been analysed. The potential for their recovery has not been highlighted, nor has the role that they could perform in improving the living conditions of peasants in other mountainous regions of the world.

Andean biodiversity

It is acknowledged that one of the ways of achieving sustainable agriculture is to maintain genetic diversity and thereby achieve a better ecological relationship. What is amazing is the fact that the pre-Hispanic cultures which ranged over the Andean highlands had domesticated a great number of species. The botanist O.F. Cook, a member of the scientific expedition that discovered the ruins of Machu Picchu, mentions that, in the sixteenth century, more domesticated species existed in the Andes than in Asia or Africa.

Since the formation of the pan-Andean empires of Tiahuanaco and Chavín, and later among the Warí, Mochica, Chimu and Nazca cultures, special interest was taken in the domestication of species. This is reflected in their representation on ceramic pieces at least 3 000 years ago. From the beginning of the fifteenth century, the Andes region constituted the Tahuantinsuyo (Inca State), and an active exchange of seeds and genetic material became widespread. Andean peasants are maintaining this biological variability through their cultivation methods as a strategy for coping with the climatic risks which commonly occur in mountain agricultures and which affect production.

In the Andes – one of the major centres of world domestication, according to Vavilov – the domestication of the potato (*Solanum tuberosum andigenum*) stands out; it includes seven different species, of which more than 400 varieties are still grown today.

Other plants were also domesticated, for example the oca, ulluco and mashwa, and these allowed crop rotation in the high regions of the Andes to be completed. In the valleys, maize was grown together with other crops of high food value, such as Andean grains (quinoa, amaranth), leguminous plants such as beans and lupins, and roots such as arracacha, yacón and chagos. To populate higher areas, cold-tolerant

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FIGURE 12
Andean region

species were adapted; for instance quinoa, which can be grown up to 3 900 m; qañiwa, which thrives at 4 000 m; and a root, called maca, which is grown up to 4 200 m (Table 5).

In using the products of various ecological areas, the Andean populations included fruits from the yunga and quechua zones in their diet. Some had very special flavours, such as the sachatomate, capulin, Peruvian pepino, various species of Cactaceae, passionfruit and mountain papayas as well as condiment, aromatic and medicinal species. It may be concluded, therefore, that the Andean region is one of the greatest centres of food plant biodiversity in the world. The considerable plant genetic variability is explained by the profuse ecological diversity that characterizes the Andes, as 18 agro-ecological areas with different agricultural uses can be identified in the central Andean region of Peru alone.

It is important to remember that the presence of numerous progenitor and wild species that are related to the domesticated species and carry the genes for adaptation to a wide diversity of high Andean climatic conditions constitutes a most valuable plant genetic resource, and its preservation urgently needs to be supported by the international community.

Conservation of Andean plant genetic resources

Until now, the survival of Andean crops has been due to the existence of numerous peasant communities which still inhabit the area and which, by preserving their traditions and their ancestral knowledge of handling as well as cultivating and using these species, have managed to prevent them from being lost.

They have also maintained numerous traditional agricultural technologies which are being undermined by erosion processes but which are fortunately the focus of various projects aimed at rescuing and improving them (Cepia, 1988; Minka, 1983, 1987; Pisa, 1989). The traditional agricultural techniques are very varied and, among others, include:

- the use of biological indicators for forecasting climatic conditions;
- the development of various agricultural tools such as the simple but effective foot-plough or *chakitaklla*;
- managing and modifying the soil to make it suitable for production using ridges and furrows or raised plots (*waru waru*); terraces which modify the land relief and which may include irrigation or drainage; and *qocha* or depressions in the ground to collect rainwater;
- various products such as organic fertilizer, for example guano from the islands;
- crop rotation and mixed cropping systems, together with pest control and the use of insect-repellent plants;
- techniques for preserving agricultural products, such as drying potatoes and other tubers and storing them for years when production is low.

Over the last 20 years, substantial work has been carried out in the field for the systematic conservation of Andean crops and their biodiversity. It was also intended to prevent genetic erosion in the face of the advance of a modern agriculture in which homogeneity and the development of high-yielding varieties reign supreme but which applies high levels of fertilizer and makes indiscriminate use of agrochemical products.

Collecting expeditions (IBPGR, INIAP) in Ecuador, Peru and Bolivia have obtained samples showing the variability of Andean crops and have ensured the conservation of a high percentage of genetic material. Of equal importance has been the compilation of descriptors of the main Andean species, done with the help of FAO's Seed and Plant Genetic Resources

TABLE 5 Main food species originating in the Andes

Crop (common name)	Latin name	Altitude *(m)*	Agro-ecological zone[1]
Tubers			
Mashwa, añu	*Tropaeolum tuberosum*	3 500 - 4 100	Suni, puna
Oca	*Oxalis tuberosa*	2 300 - 4 000	High quechua, suni
Bitter potato	*Solanum* x *curtilobum*	3 900 - 4 200	Suni, puna
	Solanum x *juzepczukii*	3 900 - 4 200	Suni, puna
Potato	*Solanum indigenum*	1 000 - 3 900	Yunga, quechua, suni
Ullucu, oca quina	*Ullucus tuberosus*	2 800 - 4 000	High quechua, suni
Roots			
Acira, Queensland arrowroot	*Canna edulis*	1 000 - 2 500	Yunga, low quechua
Arracacha, apio, Peruvian parsnip	*Arracacia xanthorrhiza*	1 000 - 2 800	Yunga, low quechua
Mauka, chago	*Mirabilis expansa*	1 000 - 2 500	Yunga, humid quechua
Maca, pepper grass, pepper weed	*Lepidium meyenii*	3 900 - 4 200	Puna
Leafcup yacón	*Polymnia sonchifolia*	1 000 - 3 000	Yunga, low quechua
Grains			
Love-lies-bleeding, cat-tail, Inca wheat, tumbleweed, kiwicha	*Amaranthus caudatus*	2 000 - 3 000	Quechua
Canihua, qañiwa, cañahua	*Chenopodium pallidicaule*	3 500 - 4 100	Suni, puna
Quinoa, quinua, suba	*Chenopodium quinoa*	2 300 - 3 900	Quechua, suni
Legumes			
Kidney bean, French bean, dwarf bean, string bean...	*Phaseolus vulgaris*	1 500 - 3 500	Yunga, quechua
Basul	*Erythrina edulis*	2 000 - 2 800	Quechua
Andean lupin, South American lupin	*Lupinus mutabilis*	500 - 3 800	Yunga, quechua, suni
Fruit-trees			
Cape gooseberry	*Physalis peruviana*	500 - 2 800	Yunga, quechua
Lucumo	*Pouteria obovata*	0 - 2 700	Yunga, low quechua
Naranjilla, lulo	*Solanum quitoense*	500 - 2 300	Yunga
Mountain papaw, papayuela	*Carica pubescens*	500 - 2 700	Yunga, quechua
Pepino	*Solanum muricatum*	500 - 2 300	Yunga
Tree tomato, tamarillo	*Cyphomandra betacea*	500 - 2 700	Yunga, quechua
Banana passionfruit, tacso, curuba, curuba passionfruit	*Passiflora mollissima*	2 000 - 3 200	Quechua

[1] Altitudes and ecological regions to which a species is best suited; species can also be grown above or below such limits under modified conditions.

Service. In recent years, emphasis has been on *in situ* conservation, i.e. in the farmers' own fields and under their cultivation systems. These measures have been backed by the organization of exhibitions such as "seed fairs" where, with the participation of local peasant communities, the conservation of plant genetic diversity is encouraged and prizes are awarded.

Potential uses of Andean crops

The marginalization of Andean crops occurred because of the low social prestige attached to certain plants that constitute the staple foods of poor populations; the laborious processes required to prepare them; and their consequent low economic return in a marginal agricultural system.

A huge promotional effort is required to increase mass consumption of these species, particularly those which stand out on account of their nutritional value, an essential condition for this being in many cases the improvement of the postharvest process. The bitter or toxic substances which the ripe fruit of some species might contain must not be a drawback, since technologies do exist for extracting them and because some compounds, such as lupin alkaloids and the saponins of quinoa, may have a pharmacological application and even be used as a biological alternative in pest and disease control.

Interesting prospects are opening up, moreover, for the expansion of some Andean crops: in the United States, Europe and New Zealand there is growing interest in the quinoa and ulluco and, throughout the world, in exotic fruit-trees such as Peruvian pepino. These crops can be processed advantageously to obtain by-products and it is possible to show that marginal yields can be modified when a secure market exists, as in the case of Brazil, for example, where arracacha gives high yields when appropriate technology is used.

For this reason, it is of utmost importance to adapt the management of traditional Andean crops to suitable technologies which enable their production to be increased. By eliminating one of the factors of their marginalization they will be able to compete under better conditions with other, more widespread crops.

Advances in research and a gradual market acceptance permit a selection to be made of those Andean crops that have an immediate chance of being rescued for food use regionally and worldwide.

In the following chapters, currently neglected native food species of the Andes are described, details are given of their present situation and an analysis is made of their production conditions and the potential they could have if the conditions of their marginalization were modified.

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Andean grains and legumes

CANIHUA
(*Chenopodium pallidicaule*)

Botanical name: *Chenopodium pallidicaule* Heller
Family: Chenopodiaceae
Common names. *English:* canihua; *Spanish:* qañiwa, cañihua (Peru), cañahua (Bolivia)

The canihua, which originated in the Andes of southern Peru and Bolivia, was domesticated by the settlers of Tiahuanaco, who established themselves on the tableland of Collao. No archaeological remains have been found connected with this plant, and the dehiscence which the seeds still display suggests that its domestication is not complete. It is important on the high plateau of Peru and Bolivia because it produces grains for human consumption at between 3 800 and 4 300 m, being very cold-resistant in its various phenological phases. At present, its cultivation and utilization are maintained at subsistence levels in these regions. One of the causes of its marginalization is the large number of people required to harvest it and its small grain size, which makes handling difficult.

Use and nutritional value

This grain has a high protein content (15 to 19 percent) and, like quinoa and love-lies-bleeding (kiwicha), a high proportion of sulphur-containing amino acids. It has the advantage of not containing saponins, which facilitates its use. The traditional and most frequent method of consumption is in the form of lightly roasted, ground grains which produce a pleasant flour called *cañihuaco*. This is consumed on its own, in cold or hot drinks, or in porridges. Over 15 different ways of preparing the whole grain and *cañihuaco* are known (as entrées, soups, stews, desserts and drinks). In the bakery industry good results have been achieved by adding 20 percent of *cañihuaco* to wheat flour, which gives the product (bread, biscuits) a pleasant characteristic colour and flavour.

Cañihuaco also has medicinal uses: it counteracts altitude sickness and fights dysentery while the ashes of its stem can be used as a repellent against insect and spider bites.

Botanical description

Chenopodium pallidicaule is an annual plant of 25 to 70 cm, with variations in its branching. Two types are differentiated: Saigua, of erect growth and with few secondary branches, and Lasta, which is very branched. It has a taproot with multiple slender ramifications. When it reaches maturity, its leaves and stem turn yellow, pink, orange, red or purple. Its inflorescences are on terminal and axillary cimas, covered by the leaves; the flowers are small, without petals and are of three types: hermaphrodite, pistillate and male sterile; the androecium is formed by one to three stamens, and the gynoecium has a unilocular superior ovary. The seed is from 0.5 to 1.5 mm in diameter, is brown or black, piriform and slightly compressed. The leaves are petiolate, rhomboid, trilobulate and alternate.

The seeds do not exhibit dormancy and can

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germinate on the plant itself if there is sufficient humidity. Because it ripens gradually, there is a spontaneous loss and dispersal of seeds, which is characteristic of the wild species. The seeds can remain for several years in the soil where *C. pallidicaule* has been grown.

Ecology and phytogeography

The crop extends from central Peru (Huaraz) to Cochabamba in Bolivia, between 3 000 and 4 000 m, with a greater concentration in the high plateau region. It is sporadic on small plots in the tableland of Bombón (Junín, Peru). Following are *C. pallidicaule*'s basic requirements:

Photoperiod. It is a day-neutral plant and shows adaptability to several environments. Grain has been produced experimentally in Finland at lat. 40°N.

Humidity. The plant needs 500 to 800 mm of rain, but it can also tolerate prolonged periods of drought. It displays extreme susceptibility to excessive humidity in the first stages of development.

Temperature. Once established, the plant is very resistant to cold and can tolerate temperatures as low as -10°C during branching, since it has an adaptation mechanism whereby the leaves cover and protect the primordia and flower stems at nightfall, thus preventing the vital parts of the plant from freezing. At the other extreme, it can tolerate up to 28°C, if it has the necessary humidity.

Soil. It prefers loamy-clayey soils, as it has sufficient phosphorus and potassium. The appropriate pH varies between 4.8 and 8.5. It exhibits tolerance to salinity.

The so-called Mama Qañiwa, Machu Qañiwa and K'ita Qañiwa, which are the closest relatives of canihua, frequently grow in wild form and among crops of bitter potato. The wild forms can attain considerable sizes under good fertility conditions. These plants are harvested and eaten during years of scarcity.

Genetic diversity

The canihua displays wide genetic diversity, with several plant forms, from erect (Lasta) to creeping (Saigua). Plant and seed colour, earliness, protein content, adaptation to soils, precipitation and tolerance of pests and diseases vary. Normally, cultivated species, escape species of the crop and wild species are found. The centre of diversity is limited to the Peruvian-Bolivian high plateau, i.e. the region between the knot of Vilcanota in Peru to the salt deposits of Uyuni in Bolivia.

Some of the cultivars known in Peru are: Cupi, Ramis, Akallapi, Huanaco, Rosada, Chillihua, Condorsaya, K'ellu and Puca. In Bolivia, cultivars include Kanallapi, Chusllunca and Issualla.

There are germplasm collections at the INIAA experimental stations of Camacani and Illpa (Puno), the San Antonio Abad University in K'ayra (Cuzco), Peru, and at the University of Patacamaya (IBTA), Bolivia, where more than 380 accessions are stored in cold, dark environments, although they are inadequate for long-term conservation.

Since selected varieties have not yet been introduced on a large scale in the two countries where it is grown, there is no danger of genetic erosion.

A complementary systematic collection of genetic variability is needed in the Lake Titicaca basin, on the Peruvian-Bolivian high plateau, in ranges and areas above 4 000 m, in high Andean valleys of the central range (Ancash, Huánuco, Junín, Huancavelica, Ayacucho and Cuzco), in arid zones bordering the salt deposits in Bolivia and lastly in the puna (high Andean plateau) and

FIGURE 13

Andean grains: A) canihua (*Chenopodium pallidicaule*); A1) hermaphrodite flower; A2) male flower; A3) fruit; A4) seed; B) quinoa (*C. quinoa*); B1) hermaphrodite flower; B2) female flower; B3) fruit; B4) seed

prepuna of northern Argentina. Collections must be taken from crops and, more especially, from wild populations which have not yet been collected, thus completing their *in situ* conservation.

Cultivation practices

Traditional cultivation takes place exclusively in dryland conditions, without fertilization, in rotation fields with bitter potato and other Andean tubers and with very little soil preparation. The seed is broadcast at the rate of approximately 5 to 8 kg per hectare. It often seems to have been sown in furrows, but these have been revealed to be no more than the ridges left over from potato growing after earthing up. Harvesting and threshing is done in several stages. These consist of pulling up the plants with their roots, shaking them so that the ripe grains fall off, then leaving them to dry for ten to 15 days and finally threshing them with curved sticks (*wajtana*). Because of *C. pallidicaule*'s gradual ripening, some grains remain and threshing is generally repeated after a further ten to 15 days. Using this technique, the farmer obtains from 400 to 800 kg of grain per hectare. The dry stems and chaff are a valued by-product for animal feeding.

However, a yield of 3 tonnes per hectare can be achieved by preparing the soil with good hoeing, sowing in furrows 40 cm apart, using seed selected according to its size (5 kg per hectare) and applying fertilizer (60-40-00 or 80-80-00). Nitrogen is applied at two stages: sowing and branching. The soil is earthed up and hoed to prevent competition. Pests are controlled in the event of production being threatened, particularly in the case of *Epicauta* sp., *Gnorimoschema* sp. and *Myzus* sp. Harvesting takes place when the plants change colour. It consists of cutting and laying the grain for threshing after 20 to 30 days or when it is completely dry. Threshing may be done by hand, using curved sticks and sieves, or it may be mechanized, using a stationary wheat thresher (reducing the revolutions to a minimum, closing off the air intake and modifying the sieve dimensions). The grain, which is covered with fine chaff, needs cleaning. Commercial yields using this technique can amount to as much as 1 500 kg per hectare.

Prospects for improvement

Among Andean grains there are many limitations because of the low distribution of their cultivation. Genetic and agronomic research, evaluation of the germplasm and processing or industrialization have been very partial in relation to the potential of the species. The difficulty of harvesting as a consequence of non-uniform grain ripening is currently one of the main limitations.

Furthermore, outside its production area, little is known about the use of this species for food. Nor is there any agro-industrial processing of the grain. The size of the grain makes processing and domestic preparation of *cañihuaco* difficult. Moreover, this traditional method is falling into disuse because of its laboriousness.

The main advantages of *C. pallidicaule* are its adaptation to the agroclimatic conditions of cold high zones above the altitude of 3 800 m, where other crops do not thrive; its nutritional value, with a 15 to 18 percent protein content and an excellent balance of essential amino acids; and the possibility of the entire plant's use as a fodder species.

Potential areas for introduction and cultivation. Cultivation could be stepped up in the flat areas of the high tableland of Peru and Bolivia and in the zones above 3 800 m of the central cordillera of the Andes.

Research, promotion and official support could result in a revival of the crop on cold land in the Andes. The lines of research and promotion necessary to initiate a wider spread of the crop are as follows:

- completing the collection, evaluation and characterization of the genetic material available in the Andean region, the priority being to obtain varieties ripening uniformly, with lesser dehiscence and large grains;
- producing improved seed and distributing it to producers;
- building efficient prototype mechanical threshers for the grain;
- implementing agro-industrial processing so as to offer attractive products which can be marketed profitably;
- publicizing its nutritional value and ways of preparing it.

QUINOA
(*Chenopodium quinoa*)

Botanical name: *Chenopodium quinoa* Willd.

Family: Chenopodiaceae

Common names. English: quinoa, quinua; *Quechua:* quinua, kiuna (Ecuador, Peru, Bolivia); *Aymara:* jiura (Bolivia); *Mapuche:* quinhua (Chile); *Chibcha:* suba (Colombia)

The quinoa is a food plant which was extensively cultivated in the Andean region by pre-Columbian cultures some 5 000 years ago and was used in the diet of the settlers both of the inter-Andean valleys, which are very cold high areas, and of the high plateaus. After maize, it has occupied the most prominent place among Andean grains.

At present, it continues to be grown in Colombia, Ecuador, Peru, Bolivia, Chile and Argentina. Its marginalization began with the introduction of cereals such as barley and wheat, which eventually replaced it. The reduction in its cultivated area in the Andean countries is also due to technical, economic and social reasons. Harvesting and threshing, which in the majority of cases are done by hand, take a great many days and the grain requires a process to remove its bitter ingredients before consumption. The prices received by farmers often do not justify their labour.

Uses and nutritional value

The parts of *Chenopodium quinoa* used as human food include the grain, the young leaves up to where ear formation begins (the protein content of the ear is as much as 3.3 percent in the dry matter) and, less frequently, the young ears. The plants nutritional value is considerable: the content and quality of its proteins are outstanding because of their essential amino acid composition (lysine, arginine, histidine and methionine); its biological value is comparable to casein and it is especially suitable for food mixtures with legumes and cereals.

Of the Andean grains, *C. quinoa* is the most versatile from the point of view of culinary preparation: the whole grain, the uncooked or roasted flour, small leaves, meal and instant powder can be prepared in a number of ways. There are numerous recipes on about 100 preparations, including tamales, *huancaína* sauce, leaf salad, pickled quinoa ears, soups and casseroles, stews, *torrejas*, pastries, sweets and desserts and soft and fermented, hot and cold, beverages, as well as breads, biscuits and pancakes, which contain 15 to 20 percent of quinoa flour.

The whole plant is used as green fodder. Harvest residues are also used to feed cattle, sheep, pigs, horses and poultry.

The leaves, stems and grain have medicinal uses and the properties attributed to it include cicatrization, anti-inflammation, analgesia against toothache and as a disinfectant of the urinary tract. It is also used in the case of fractures and internal haemorrhaging and as an insect repellent.

Its production potential is good. Because of this, its cultivation is spreading to other countries. With adequate soil preparation, fertilization and pest and disease control, yields of more than 3 to 4 tonnes per hectare can be obtained. In recent years, it has been introduced on the international market, fetching prices in excess of US$1.5 per kg.

Botanical description

C. quinoa is an annual herbaceous plant, measuring 0.20 to 3 m in height, depending on environmental conditions and genotype. It has a racemose inflorescence (a panicle with groups of flowers in glomerules); small, incomplete, sessile flowers of the same colour as the sepals and they may be hermaphrodite, pistillate or male sterile. The stamens have short filaments bearing basifixed anthers; the style has two or three feathery stigmas.

The fruit occurs in an indehiscent achene, protected by the perigonium. The seeds are 1 to 2.6 mm and are white, yellow, red, purple, brown or black. The leaves show pronounced polymorphism: rhomboid, deltoid or triangular. The taproot is densely branched.

Ecology and phytogeography

The cycle varies from 120 to 240 days and is suited to various environmental conditions. The phenological phases are emergence; two, four and six true leaves; branching; start of ear formation; full formation of ear; start of florescence; florescence or anthesis; woody grain; soft grain; and physiological maturity.

The quinoa has the ability to adapt to adverse environmental conditions such as cold and drought. Its seeds do not exhibit dormancy and they germinate when conditions are suitable, even on the plant itself although, in the wild forms, they may remain in the soil for two to three years without germinating.

C. quinoa's traditional cultivation area extends from lat. 8°N to lat. 30°S, as the plant adapts to different conditions of humidity, altitude and topography. Its requirements are:

Precipitation. This depends on the agro-ecological zone and the genotype to which it belongs. It varies from 250 mm (the area of salt deposits in Bolivia) to 1 500 mm in the inter-Andean valleys. Although it shows strong resistance in periods of drought, it requires sufficient humidity at the commencement of cultivation.

Temperature. It tolerates down to -5°C in the branching phase, depending on the ecotype and the duration of the minimum temperature. Its ontogenic resistance to cold and drought is very variable. Ecotypes exist which are resistant to temperatures of down to -8°C and survive for 20 days (mean monthly temperature).

Soil. It prefers easily worked, semi-deep soils, with good drainage and a supply of nutrients. It is suited to acid soils with a pH of 4.5 (in Cajamarca, Peru) and alkaline soils with a pH of up to 9.5 (in Uyuni, Bolivia), depending on the ecotype. Acceptable production is also obtained both on sandy and clayey soils.

Genetic diversity

The nearest wild species to *C. quinoa* are *C. hircinum* and *C. berlandieri*, which have the same number of chromosomes ($2n = 4x = 36$), and *C. pallidicaule* with $2n = 2x = 18$ chromosomes.

Sympatric wild populations of domesticated populations exist under cultivation, and morphological and electrophoretic similarities can be noted between one and the other in each locality, which indicates that domesticated quinoas are generally accompanied by wild populations in their various distribution areas.

Cultivated quinoas exhibit great genetic diversity, showing variability in the colouring of the plant, inflorescence and seeds, types of inflorescence, protein content, saponin content, betacyanine and calcium oxalate crystals in the leaves, so that a wide adaptation to different agro-ecological conditions may be seen (soils, precipitation, temperature, altitude, resistance to frost, drought, salinity or acidity).

From the point of view of its variability, it may be considered an oligocentric species, with an ample centre of origin of multiple diversification. The Andean region and, within it, the shores of Lake Titicaca, are where the greatest diversity and genetic variation occur. The main varieties known in this region are: in Peru, Kancolla, Cheweca, Witulla, Tahuaco, Camacani, Yocará, Wilacayuni, Blanca de Juli, Amarilla de Maranganí, Pacus, Rosada y Blanca de Junín, Hualhuas, Huancayo, Mantaro, Huacariz, Huacataz, Acostambo, Blanca Ayacuchana and Nariño; in Bolivia, Sajama, Real Blanca, Chucapaca, Kamiri, Huaranga, Pasancalla, Pandela, Tupiza, Jachapucu, Wila Coymini, Kellu, Uthusaya, Chullpi, Kaslali and Chillpi; in Ecuador, Inbaya, Chaucha, INIAP-Cochasqui, Tanlahua, Piartal, Porotoc, Amarga del Chimborazo, Amarga de Imbabura and Morada; in Colombia, Dulce de Quitopampa; in Argentina, Blanca de Jujuy; and in Chile, Baer, Lito, Faro and Picchaman.

The risks of genetic erosion are due not only to the loss of viability in gene banks (at present it exceeds 15 percent annually) but also that occurring in the areas of diversification, particularly in places where cultivars and modern varieties are promoted for commercial purposes. The case of wild species is even more delicate, with small, isolated populations which have not been collected in time and which are inexorably vanishing. There are also risks from environmental factors and natural disasters. *In situ* conservation is an alternative, although there are difficulties of a socio-economic nature and also regarding institutional support.

Throughout the Andean region there are several gene banks where over 2 000 accessions are preserved in cold-storage rooms: in Peru, at the experimental stations of Camacani and Illpa (Puno), K'ayra and Andenes (Cuzco), Canáan (Ayacucho), Mantaro y Santa Ana (Huancayo), Baños del Inca (Cajamarca); in Ecuador, at the Santa Catalina station of INIAP (it has a cold-storage room); and in Bolivia, at the Patacamaya station of the IBTA.

The areas of genetic diversity where there are still no collections are the islands of Lake Titicaca; the areas above 3 900 m in Peru and Bolivia; the semi-arid inter-Andean valleys; the salt-pans; the valleys of the eastern slope of the Andes; and the cold zones of Argentina.

Cultivation practices

The traditional cultivation technique consists of sowing under dry conditions in a crop rotation with potato or on strips in maize crops, with little soil preparation and using only the residual organic fertilizers from the preceding crop. Sowing density varies between 15 and 20 kg of unselected seed per hectare. As traditional growers always look for safety in cultivation, they therefore sow several ecotypes at different times and in different locations. Cultivation work is limited to one or two hoeings, with occasional earthing up, particularly in the inter-Andean valleys. There is no pest and disease control. The plants are harvested when they reach physiological maturity and are laid for 30 to 45 days, after which they are threshed on well-trodden ground, beaten with curved sticks (*wajtana*) or trampled by animals. Yields range from 400 to 1 200 kg per hectare, depending on the region.

Experimental results show that yields can be increased by preparing the soil well, applying 80-40-00, applying fractionated nitrogen during sowing and earthing up. It is recommended that the crop be sown in furrows spaced 40 to 80 cm apart, using 10 kg per hectare of selected seed and hoeing during the first phenological phases, with earthing up particularly in the case of valley-growing quinoa and control of the main pests. The crop can be harvested using either combine harvesters or stationary harvesters. Yields of up to 5 000 kg per hectare of grain can be achieved and a by-product of harvesting is 5 to 10 tonnes per hectare of chaff for feeding livestock. These yields can be produced under suitable climatic conditions (rain and temperature), which do not always prevail in the different agro-ecological areas of the Andes.

Prospects for improvement

One of the main current limitations of cultivation stems from the fact that almost all the traditional varieties contain saponins in a greater or lesser quantity, which give the grain a bitter flavour. However, varieties with a low saponin content do exist, for example Blanca de Junín, as do some which are almost free of saponin, such as Sajama and Nariño.

For centuries, the quinoa has been considered a food of low social prestige, although this prejudice is slowly changing. There needs to be a greater awareness of its nutritional value.

Prospects for improving propagation and cultivation techniques are fairly encouraging. Agro-industrial processing is a decisive factor for the present and future development of the crop. It enables quality and use to be optimized and aggregate value increased and it makes marketing easier, thus encouraging growers not only to improve productivity but also to increase the area sown.

Experiments in projects such as that of COPACA (1990) in publicizing knowledge about the quinoa, among other crops, open up prospects of the crop spreading on a very large scale, in view of its strategic importance in feeding populations, especially the rural population. It may also be extended to the urban and peripheral populations and be of interest in food security programmes.

There are possibilities of its being introduced into the market economy and of its contributing to the generation of adequate incomes. However, there are still an excessive number of intermediaries in the marketing process and quality parameters still have to be determined in terms of the market and exports.

Potential areas for introduction and cultivation. The rate of distribution and cultivated area attained with the quinoa before the sixteenth century could be recovered and its cultivation in arid and semi-arid or marginal areas increased. In Venezuela, good results have been produced by trials carried out in the Mérida and Maracay areas with a view to its future introduction in the Departments of Mérida, Trujillo and Lara. In Colombia, these trials included the savannah of Bogotá and the Departments of Boyacá, Cundinamarca, Valle, Huila, Nariño, Santander and Antioquía.

In Ecuador it has been introduced throughout the Andean region, mainly in the provinces of Carchi, Imbabura, Pichincha, Cotopaxi, Chimborazo, Loja and Tunguragua. Its cultivation is being promoted by private firms in low, warmer agro-ecological areas for export.

In Peru, it has been introduced throughout the Andean region from Piura to Tacna, although on the coast its potential is good, particularly as regards export. In Bolivia, it has also been introduced into the Andean region. Its yield can be increased in the area of the salt-pans and it can be incorporated in the yungas.

It would be feasible to introduce the crop into Honduras and Guatemala as well as the central states of Mexico (México, Puebla, Guerrero, Tlaxcala and Oaxaca). It has been researched in the United States and is now sown in Colorado, Texas, New Mexico and Utah. In the Himalayas, it is grown with acceptable results.

The main advantages of this crop are its ability to produce a grain of high biological quality and the existence of germplasm suited to various ecological conditions. Furthermore, the current knowledge and use of this species by the peasants should be extended.

Lines of research

- Completing the collection, evaluation, characterization, documentation and exchange of germplasm in the various countries of the Andean region; improving the installations and equipment of current gene banks.
- *Genetic and agronomic improvement:* selecting a wide range of early varieties which have a low saponin content, a large grain and which are high-yielding and resistant to frost, drought and salinity; improving the plant's uniformity of architecture and of ripening to facilitate mechanized harvesting; carrying out integrated pest and disease control; establishing a basic genetic seed production programme and commercial seed propagation programme for the various agronomic areas of the Andes.
- *Postharvest and processing:* perfecting technology for the removal of saponins from the grain while avoiding loss of nutritional value; encouraging industrial processing.
- *Nutritional value and use*: carrying out chemical and nutritional characterization of the saponin and its use in the pharmacopoeia; publicizing nutritional characteristics and culinary versatility.
- *Commercialization and marketing*: evaluating domestic consumption, stimulating demand and including it in food assistance programmes; improving information on prices and quality parameters; specifying health procedures for export.

ANDEAN LUPIN (*Lupinus mutabilis*)

Botanical name: *Lupinus mutabilis* Sweet
Family: Fabaceae
Common names. *English:* Andean lupin, South American lupin; *Quechua:* tarwi (Peru, Bolivia); *Aymara:* tauri (Bolivia); *other indigenous languages:* chocho, chochito (Ecuador and northern Peru), ccequela (Peru [Azángaro]), chuchus (Bolivia); *Spanish:* altramuz, lupino, chocho

The Andean lupin is a leguminous plant that was domesticated and grown by the ancient settlers of the central Andean region from pre-Incan times, as indicated by seeds found in tombs of the Nazca culture and the plant's representation on Tiahuanaco pottery. As in earlier times, Andean populations still use the seeds as a food today. They were very important as long ago as the pre-Hispanic era, figuring foremost among foods because of their high protein content.

Lupinus mutabilis is still grown from Ecuador to Chile and northern Argentina under different production systems. It was displaced by European crops and, because of this, has been one of the native species most affected by marginalization. The grain has a high alkaloid content which imparts a very bitter taste and a process is therefore needed to eliminate it, thus giving it a disadvantage compared with other introduced legumes. The result has been a reduction in cultivated area of *L. mutabilis*, despite its agronomic and nutritional benefits, such as the fixing of atmospheric nitrogen (more than 100 kg per hectare), cold resistance and a high protein and oil content. Its marginalization may have been influenced by the fact that it was eaten mainly by the indigenous population, as well as by its variable yield: on peasant plots, 300 to 600 kg per hectare are obtained; under suitable conditions, 3 500 kg, and experimentally, 7 000 kg per hectare.

Uses and nutritional value

The Andean lupin is not only an important source of protein (42.2 percent in the dry grain, 20 percent in the cooked grain and 44.5 percent in the flour), but also of fat which in the dry grain is 16 percent and in the flour 23 percent. It is used for human consumption after the bitter taste has been removed, a process for which there are several methods. Preparation varies according to the region and the occasion on which it is eaten: *cebiche serrano*, soups (cream of Andean lupin); stews (*pipián*, a kind of fricassée); desserts (*mazamorra* custard with orange) and soft drinks (papaya juice with Andean lupin flour).

Industrially, flour is obtained which is used in a proportion of up to 15 percent in breadmaking – it has the advantage of considerably improving the protein and calorific value of the product. It also allows the bread to be kept longer because of the retrogradation of the starch, a greater volume being obtained owing to the emulgent properties of the sweet lupin's lecithin. The alkaloids (sparteine, lupinine, lupanidine, etc.) are used to control ectoparasites and intestinal parasites of animals. Occasionally, farmers use the Andean lupin's cooking water as a laxative and to control pests and diseases. In the flowering state, the plant is incorporated into soil as green manure and effectively improves the quantity of organic matter and the structure and moisture retention of the soil. Because of its alkaloid content, it is frequently sown as a hedge or to separate plots of different crops, preventing damage which animals might cause. Harvest residues (dry stems) are used as fuel because of their high cellulose content which provides an appreciable calorific value.

Botanical description

L. mutabilis is an annual plant varying in height from 0.4 to 2.5 m, depending on the genotype and environment in which it is grown. It has a taproot with a thick main stem, reaching up to 3 m. The ramified secondary roots have symbiotic nodules with bacteria of the *Rhizobium* genus. The stems are cylindrical and woody. The leaves are palmate and digitate. It has racemose inflorescences with several flower verticils, each with five flowers, whose colours range from blue, purple, sky blue, pink to white. The androecium is formed by ten dorsifixed and five basifixed stamens. Because of flower abscission, 50 to 70 percent of the flowers do not form fruit, especially on secondary and tertiary branches. The fruit occurs in a pubescent, indehiscent pod in the cultivated species, with some dehiscence in the semi-cultivated and wild species. It is elliptical or oblong, pointed at both ends, with approximately 130 pods per plant. The seed is lenticular, 8 to 10 mm long and 6 to 8 mm wide. Its colour varies between black and white, through bay, dark grey, light grey and greenish yellow. A hardened integument, containing alkaloids, accounts for 10 percent of the seed. The weight of 100 seeds is between 20 and 28 g.

The growing cycle varies between 150 and 360 days, depending on the genotype and whether ripening of the central stem alone is taken into account or that of other branches. The various phenological phases are: emergence; first true leaf; formation of the raceme on the central stem; flowering; podding; pod ripening; and physiological maturity. The seeds exhibit dormancy through immaturity, since they require a post-ripening phase before germinating. In wild species of *Lupinus*, dispersion is spontaneous through dehiscence and may extend as far as several metres.

Ecology and phytogeography

L. mutabilis is grown in temperate cold areas (Venezuela, Chile and northern Argentina), in inter-Andean valleys and on high plateaus, from 2 000 to 3 850 m, although good yields have been obtained in experiments at sea level. The requirements of *L. mutabilis* are:

Photoperiod. It is apparently unaffected by this factor, although it is grown more under short-day conditions.

Precipitation. Its requirements are between 350 and 800 mm and it is grown exclusively under dry farming conditions. It is susceptible to excessive humidity and moderately susceptible to drought during flowering and podding.

Temperature. It does not tolerate frosts during the raceme formation and ripening phase, although some ecotypes grown on the shores of Lake Titicaca have a greater resistance to cold.

Soil. It prefers loamy-sandy soils, with an adequate balance of nutrients, good drainage and a pH between 5 and 7; on acid soils, *Rhizobium* nitrogen-fixation is very low.

Cultivation continues in the traditional way in Ecuador, Peru and Bolivia, although introductions have now been made with good results in Venezuela, Colombia, Chile, Argentina, Mexico and European countries.

Genetic diversity

The Andean lupin displays a wide genetic diversity, with great variability in its architecture, adaptation to soils, precipitation, temperature and altitude. This is also the case with earliness, protein, oil and alkaloid content and disease tolerance. The colour of the seed, plant and flower varies. Its centre of origin would seem to be located in the Andean region of Ecuador, Peru and Bolivia, since the greatest genetic variability is found there. In this region, 83 species of the *Lupinus* genus have been identified.

Known varieties and cultivars are numerous: in Peru, Andenes 80, Cuzco, K'ayra, Carlos Ochoa, Yunguyo, Altagracia, H6, SCG-9, SCG-25, SLP-1, SLP-2, SLP-3, SLP-4 and SLP-5; in Bolivia, Toralapa and Carabuco; and in Chile, Inti.

Several working collections are kept in universities, at research institutes and in technical cooperation projects throughout the Andean region. More than 1 600 accessions are kept in cold-storage rooms at several experimental stations. The main ones are in Peru (K'ayra in Cuzco, Santa Ana in Huancayo, Illpa and Camacani in Puno, Baños del Inca in Cajamarca and Canáan in Ayacucho), Bolivia (Patacamaya, Toralapa and Pairumani) and Ecuador (Santa Catalina).

The high fat content of the seeds reduces germination times; losses may be as much as 20 to 25 percent annually, hence continuous regeneration of the material is required.

No genetic erosion has yet been observed in the field, since the introduction of improved varieties is not significant. *In situ* conservation would be a good alternative, particularly for the wild species.

The areas of genetic diversity of cultivated or wild species which need to be collected are situated above 3 800 m in semi-arid regions, in deep inter-Andean valleys, on the eastern slope of the Andes, on the low ridges of the Peruvian coast, at the foot of the Venezuelan mountains, in the Colombian savannah, in northern Argentina, in the yungas of Bolivia and in Chile, in Concepción and Chiloé in the south, and in the northern areas.

Cultivation practices

The traditional cultivation practice consists of sowing after minimum tilling, particularly on thin soils and in high areas because of the sparse growth of weeds and the need to conserve humidity. The crop is generally cultivated in rotation with potato or cereals, without the use of fertilizers or manures. Sowing density varies from 100

FIGURE 14

A) Andean lupin (*Lupinus mutabilis*); A1) flower; A2) legume; A3) seed; B) kiwicha (*Amaranthus caudatus*); B1) flower; B2) fruit

to 120 kg per hectare of unselected seed, which is broadcast. Cultivation work is limited to hoeing. Harvesting takes place when the plants have reached full maturity. The seeds are separated from the pod by blows from a curved stick or they are trampled by livestock. Threshing is completed by winnowing. Using this technique, yields range between 500 and 1 000 kg per hectare, depending on the region and ecotypes used.

The improved cultivation technique consists of sowing on pre-prepared soil that has been fertilized with the formula 0-60-00 or 0-80-60, depending on soil fertility. The requirement is 80 to 90 kg of selected seed per hectare, disinfected against *Colletotrichum* sp. Two or three seeds at a time are put into furrows spaced 60 to 80 cm apart. Weeding is done in the branching phase, together with control of the seed weevil (*Apion* sp.) and *Epicauta* sp. Harvesting takes place when the central stem (high plateau of Peru and Bolivia), or primary and secondary branches (inter-Andean valleys) are mature. The usual method of harvesting is reaping, laying, threshing, winnowing and storage – laborious and labour-intensive activities. Stationary soybean and kidney bean threshers have been used with good results, and prototype stationary threshers with a 0.5 to 1 h.p. motor have even been designed. However, the efficiency of the latter equipment is still not adequate (processing 500 to 600 kg per day). Yields reach 3 500 and 5 000 kg per hectare.

Cultivation is being developed with greater interest in Peru, Bolivia and Ecuador (the agronomic situation of Andean lupin utilization in Ecuador has been described). The alkaloid-free variety, Inti, bred in Chile by von Baer, is currently available.

Prospects for improvement

Cultivation of the Andean lupin, like other crops of Andean origin, is limited by the lack of continued support for research and promotion. The main limitation is the alkaloid content of the seed and plant itself. Alkaloids give them a sharp, bitter taste and have to be removed by way of various laborious processes. The traditional and best-known method is cooking, followed by rinsing for several days. The harvest residues cannot be used as fodder until alkaloid-free varieties are available. Although, at present, there are ecotypes with a low alkaloid content and one variety which is free of them, these still show adaptation difficulties, low resistance to pests and diseases, a long vegetative period and little growth vigour. Its nutritional value and forms of use are not widely known, which is why its consumption is not more widespread among the population. Moreover, market supplies of Andean lupins which have had their bitter flavour removed are temporary and limited to producer areas.

Processing methods are still unsophisticated and not very efficient. With advanced agro-industrial techniques, the crop could be extended and promoted and its prices improved. It has production potential and prospects for use as an oilseed plant, source of protein, nitrogen-fixer and producer of alkaloids, with applications in animal and plant health.

Cultivation could be extended to marginal areas: to do this, more genetic research is needed on resistance to drought, frosts, hail and soil acidity. Through selection and crossing, there is potential for the development of varieties that are free of alkaloids and have desirable agronomic and productive characteristics.

Potential areas for introduction and cultivation

Cultivation could be increased in the Andes of Ecuador, Peru and Bolivia, both in traditional areas where it was abandoned or displaced and in new areas, by introducing varieties with a low alkaloid content or free of alkaloids. As an oilseed plant, it could contribute to alleviating the oils and fats deficit in the Andean countries. Its use has even been considered as fodder in the cold areas of Europe. Early varieties (150-day growing period) can be sown in rotation with cereals in the mountain ranges or with other industrial crops on the coast of Peru.

In Colombia, the experience of its introduction into Boyacá, Cundinamarca, Nariño and Antioquía has been favourable, as it has also in Trujillo, Mérida and Lara in Venezuela. In northern Argentina, Uruguay and Paraguay, it could be introduced into high cold areas. This needs further research, particularly in Uruguay and Paraguay. In Argentina, there are gene banks with a limited amount of material, and research has been carried out at the Universities of Córdoba and Buenos Aires and at INTA.

In Chile, the species *L. luteus*, *L. albus* and *L. angustifolius* are grown; these are used for making flour for bread, in the oil industry and as a supplementary food for schoolchildren and hospitals. Production areas are concentrated in Concepción, Valdivia and Gorbea. The early and sweet varieties could be grown in the country's high areas.

In Central America, its introduction could result in an encouraging spread of the crop because of the suitable agro-ecological conditions. In Mexico, good results have been obtained experimentally, reaching the point where the tertiary branches are harvested. Its cultivation could spread to Oaxaca and Guerrero and part of other states such as México (Toluca), Tlaxcala and Puebla, as well as to Honduras, Guatemala and Nicaragua. The possibilities are more limited in the United States and Canada because of the technological progress of other crops such as soybean and sunflower.

Lines of research

Lines of research and technological development to promote the crop are as follows:

- *Germplasm:* completing the collection, evaluation, documentation and exchange of genetic material.
- *Genetic and agronomic improvement:* obtaining alkaloid-free varieties, incorporating earliness, resistance to *Colletotrichum gloeosporioides*, resistance to drought, frost and soil acidity; breeding high-yielding varieties, uniformity in ripening of the main stem and side branches, as well as architecture with basal branching; studies on integrated pest and disease control; formation of genetic nuclei; and obtaining basic and certified seed from the main varieties.
- *Postharvest and industrialization:* carrying out studies on grading, cleaning and adaptation to agro-industry; introducing techniques to remove alkaloids, while avoiding any loss of nutritional value; research on obtaining processed products for human use; promoting consumption, methods of preparation and biological value.
- *Marketing and consumption:* studying marketing channels and costs and the potential of domestic and foreign markets; providing information on prices and quality parameters; suggesting ways of stimulating demand and establishing social programmes for mass consumption.

LOVE-LIES-BLEEDING (*Amaranthus caudatus*)

Botanical name: *Amaranthus caudatus* L.

Family: Amaranthaceae

Common names. *English:* love-lies-bleeding, Inca wheat, cat-tail, tumbleweed; *indigenous languages:* kiwicha (Peru), achita (Peru [Ayacucho, Apurímac]), achis (Peru [Ancash]), coyo (Peru [Cajamarca]), coimi, millmi (Bolivia), sangoracha, ataqo (Ecuador)

Love-lies-bleeding is a grain originating in South America, where it was also domesticated. The chronicler, Cobo, wrote in 1653 that, in the city of Guamanga (Ayacucho), delicious sweets were prepared from bledos (*Amaranthus caudatus*) and sugar. A similar species, the huautli (*A. hypochondriacus*), was extensively grown in Mesoamerica and is frequently mentioned by writers in connection with Aztec customs and ceremonies.

Since the colonial era, the cultivated area of love-lies-bleeding has decreased considerably. However, it is still grown in Ecuador, Peru, Bolivia and Argentina because of the persistence of Andean farmers, and continues to be important because of its excellent nutritional quality. It is efficient at fixing carbon dioxide, does not have photorespiration and requires less water to produce the same amount of biomass as cereals.

The grain's nutritional value is high and can be as much as to 12 to 16 percent protein, while the balance of amino acids is very good, with a fair proportion of these containing sulphur: lysine, methionine and cysteine. It does not contain saponins or alkaloids and the leaves are edible. In the human diet it is preferably eaten split or after the split grain has been ground, giving a very agreeable flour.

The grain is also cooked whole. Over 50 ways of preparation are known: the leaves are eaten in salads and the grains are also used to make soups, custards, stews, desserts, drinks, bread and cakes.

Agro-industry makes flour which is used up to 20 percent as a wheat substitute in breadmaking. It is also used to make an instant chocolate powder, syrups and sweets. A study has been made of the use of vegetable colouring matters, which are found up to 23 percent in the ear and are highly water-soluble and unstable in light.

Harvest residues are used for livestock feeding because of the protein content and suitable digestibility. The ground grain is used to control amoebic dysentery.

Botanical description

A. caudatus is an annual plant of 0.4 to 3 m. It has a taproot and numerous, very ramified side roots. The leaves are petiolate, oval, opposite or alternate and green or purple. The paniculate, monoecious inflorescence ranges from erect to decumbent, with attractive colours -- green, yellow, orange, pink, red, purple and brown. The flowers are small, unisexual, staminate or pistillate; the males have three to five stamens and the females have a monospermous superior ovary. The fruit is in a pyxidium; the seeds are small (from 1 to 1.5 mm in diameter), generally white, smooth, shining, slightly flattened, although sometimes yellowish, golden, pink, red and black; and there are 1 000 to 3 000 seeds per gram.

The percentage of allogamy ranges between 10 and 50 percent, even within individuals of the same population. Crossing depends on the wind, the number of pollinating insects, pollen production, etc. Generally, the seeds do not exhibit dormancy and, as they contain moisture, they may even germinate on the plant. Dehiscence occurs at intervals and is a common characteristic among the wild species. Seeds are dispersed over great distances from the parent plant.

Ecology and phytogeography

A. caudatus extends from Ecuador to northern Argentina, growing in temperate areas and inter-Andean valleys from sea level to 3 000 m. Its main requirements are:

Photoperiod. It prefers short days, although it shows great adaptability to different environments and can flower with 12- to 16-hour days.

Precipitation. Water requirements range from 400 to 800 mm. However, acceptable production levels are obtained with 250 mm. Although it requires reasonable precipitation for germination and flowering, it can tolerate periods of drought after the plant has become established. Crops have been observed in areas with 1 000 mm of annual precipitation.

Temperature. It is sensitive to cold and can tolerate only 4°C in the branching state, with 35 to 40°C as the maximum temperature.

Soils. It prefers easily worked, sandy soils with a high nutrient content and good drainage, although it can adapt to a broad range. The ideal pH is 6 to 7, although crops have been found in acid soils and at a pH of 8.5. It shows tolerance to aluminium toxicity. In the wild form, and tolerated within crops, there are many wild species of *Amaranthus* as well as species tolerated among cultivated crops. In the Andes, the most important are: *A. hybridus*, *A. spinosus*, *A. dubius*, *A. palmeri*, *A. viridis*, *A. blitum* and *A. tricolor*, which are found growing with maize and other crops. They generally have dark seeds and, under suitable conditions of fertility, can develop great vigour and size, to the point of being confused with the cultivated plant. The leaves are used for human consumption.

Genetic diversity

A. caudatus has a wide genetic variety and diversity of plant forms, ranging from erect to completely decumbent. It shows great variation in seed colour; earliness; protein content; types of ear; adaptation to soils, climates, precipitation and temperatures; disease resistance; and colouring content. The greatest genetic variation is noted in the Andes (Ecuador, Peru, Bolivia and Argentina).

The Kiwicha [love-lies-bleeding] Research Programme, carried out by the University of Cuzco, Peru, has selected among others the varieties Noel Vietmayer and Oscar Blanco, while INIAA in Cajamarca has selected the varieties Roja de Cajabamba and San Luis.

Over 600 accessions are stored in the gene banks. In Peru, they are found at the experimental stations of K'ayra (Cuzco), Canáan (Ayacucho), Baños del Inca (Cajamarca), Santa Ana (Huancayo) and Tingua (Huaraz); in Ecuador, at the Santa Catalina Experimental Station; in Bolivia, at the Pairumani Experimental Station; and in Argentina, at the University of Córdoba.

There are many areas of genetic diversity which need to be scoured for collecting, mainly the tropical and subtropical valleys of the eastern range of the Andes of Peru, Bolivia and Ecuador as well as the western valleys of the Andes and semi-arid areas of Peru and Bolivia (Ayacucho and Cochabamba, respectively).

Cultivation practices

A. caudatus cultivation is maintained in the traditional way in the Andes of Peru, Bolivia, Ecuador and Argentina. Different forms and systems of cultivation are observed, including: direct sowing; transplanting, with irrigation or on dry land; growing together with maize; interplanted, to separate fields from other crops; as a border; sowing as a horticultural plant close to houses and plots on small farmsteads; and extensive cultivation.

It is traditionally sown under dry conditions, on pre-prepared ground, often together with maize and, in the case of single sowing, in furrows spaced 80 cm apart and fed with a constant stream of water. When the plant reaches 20 to 25 cm, the first weeding is done, and also thinning if the seedlings are clustered together or need to be moved to spaces with a greater availability of water. The plants are also sown in seed beds for subsequent transplanting to irrigated land. Harvesting takes place before the plant is fully mature so as to forestall seed fall. It consists of cutting the plants 20 cm from the soil with sickles and forming small sheaves which are left to dry above the furrows. To remove the seeds, they are beaten with sticks on sheets spread over the ground or on well-trodden earth and then sifted or winnowed to separate the grain from the chaff. Using this technique, farmers can obtain from 500 to 1 500 kg per hectare.

Crop improvement consists of adequate preparation of the soil, direct sowing, with a density of 4 to 6 kg of selected seed per hectare, in furrows set 80 cm apart, and the application of fertilizers according to the quantity of nutrients available in the soil (50-60-20 or 80-80-20 in Peru). Cultivation work consists of one or two weedings, light earthing up to prevent collapse from the weight of the inflorescences and control of the main pests and diseases.

Without waiting for the plant to mature completely, harvesting is done when its lower leaves show signs of yellowing and there is some basal dehiscence and dry seeds. The plant is cut and left to dry in piles before being beaten with curved sticks (in which case it takes 20 to 25 days' work per hectare), or using stationary wheat threshers in which the size of the sieves, air blast and motor revolutions have been modified. Yields obtained vary between 2 000 and 5 000 kg per hectare in Peru and 900 and 4 000 kg per hectare in Ecuador.

Prospects for improvement

An increase in production indices, followed by support for industrial processing in rural areas which would increase producers' incomes, would stimulate local consumption and, if there was a surplus, exports. The standards achieved in research, evaluation and characterization of the germplasm available, together with the advances in its genetic, agronomic, biochemical and industrial improvement, constitute a sound basis, so that technological progress is encouraging as far as the utilization of this plant's productive potential is concerned. The plant needs to be spread more widely among both producers and consumers: its nutritional value and the uses and ways in which it is consumed are not very well publicized in Andean countries. The advantages of love-lies-bleeding are the low cost of the unprocessed grain, the absence of any special treatments being required and the fact that it is willingly accepted by consumers.

Lines of research

The main aspects of research which need to be completed are:

- *Germplasm and improvement:* completing the collection of germplasm in certain areas of the Andean region, as well as evaluation, characterization and documentation; breeding varieties with less dehiscence, greater uniformity of ripening, resistance to drought, frosts and soil alkalinity, tolerance of the main pests and diseases and greater colouring content; promoting the establishment of basic and certified seed beds of the main varieties.
- *Postharvest and industrialization:* developing prototypes of machines which enable harvesting to be done effectively, as well as cleaning and selection; developing industrial processing technologies to obtain new products, particularly to boost the supply of foods for mothers and infants.

A publicity campaign also needs to be launched in urban areas. As far as marketing is concerned, studies must be carried out on outlets and costs, on the potential of domestic and foreign markets and on quality standards.

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Andean tubers

OCA
(*Oxalis tuberosa*)

Botanical name: *Oxalis tuberosa* Molina
Family: Oxalidaceae
Common names. *English:* oca, oxalis; *Quechua:* oqa, ok'a; *Aymara:* apilla; *Spanish:* oca (Peru, Ecuador), oca, ibia (Colombia), ruba, timbo, quiba (Venezuela), papa roja, papa colorada, papa extranjera (Mexico)

Oxalis tuberosa is a crop native to the Andes. Together with the potato, the domestication of this and other Andean tubers in the central region of Peru (lat. 10°S) and northern Bolivia (lat. 20°S), where the greatest diversity both of cultivated and wild forms is found, is thought to have given rise to agricultural activity in the higher agro-ecological areas of the Andes. The migrations of pre-Columbian communities extended its cultivation to lat. 8°N in Venezuela and lat. 25°S in northern Argentina and Chile. Its cultivation was introduced into Mexico about 200 or 300 years ago and, nowadays, it is grown relatively extensively in the region of the Transverse Neovolcanic Axis. Oca was introduced into Europe in the last century and, even though it was produced as a new vegetable, it did not become established as a permanent crop. It is known to have existed in New Zealand since 1860 and its cultivation seems to have gained popularity in the last 20 years.

The oca is sown together with the ullucu, mashwa and native potatoes on plots from 30 to approximately 1 000 m^2. It is therefore difficult to tell what its cultivated area and production is. However, it is estimated that 20 000 ha are sown annually in Peru, with an average production of 3 to 12 tonnes per hectare, although some experimental selections and treatments have produced as much as 97 tonnes per hectare.

Uses and nutritional value

Oca is first sun-dried to make it sweeter and then parboiled, roasted or prepared as *pachamanca* (meat roasted in a hole in the ground).

The dried, frozen tuber is called *khaya*. If it is washed after freezing, a whiter product called *okhaya* is obtained which is considered to be of superior quality. The flour of the latter is used to make porridges and desserts. Oca is first and foremost a good source of energy; its protein and fat content is low.

Botanical description

O. tuberosa is an annual, herbaceous plant that is erect in the first stages of its development, and decumbent or prostrate towards maturity. The tubers are claviform-ellipsoid and cylindrical, with buds on the whole surface, and variegated in colour: white, yellow, red and purple.

The leaves are trifoliate, with petioles of varying length (2 to 9 cm). The inflorescences consist of four or five flowers. The calyx is formed by five pointed, green sepals. The corolla has five purple-striped, yellow petals; ten stamens in two groups of five; and a pistil that is shorter or longer than the stamens. Propagation is almost exclusively by the tubers. The flower structure has

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an efficient mechanism which facilitates cross-pollination.

Ecology and phytogeography

Oca is grown from 3 000 to 4 000 m, from Colombia to Chile. However, the greatest concentration is found between 3 500 and 3 800 m, in the suni agro-ecological zone (mountain slopes).

Wild species of the genus *Oxalis* are found on the low ridges of the Peruvian coast, or growing sympatrically with cultivated oca in the Andes and on the edges of forests.

Genetic diversity

The basic number of chromosomes has been established as x = 11. There are reports of ocas that are close to pentaploid (2n = 2x = 58) and hexaploid (2n = 2x = 66) and also of hexaploid cultivated ocas. The frequency of diploids, triploids, tetraploids, pentaploids and hexaploids as well as those that are not exactly euploid should be clarified. The role of the 2n gametes in the formation of the polyploid complex and the nature of the F_1 and F_2 material needs to be studied.

The pattern of variability in the oca seems to be fairly complex. In fact, cultivated forms have hitherto been grouped together into a single species which includes several shapes and colours of tuber.

The self-incompatibility system present in the oca and consequent cross-pollination, together with the aesthetic selection made by Andean farmers, must have had an influence on the existence of the wide variety of tuber colours and shapes, as well as the number and depth of "eyes" or "buds".

The wide variability found in the colour of the tubers suggests a continual variation, since colours range from white to black, with various hues of yellow, pink and red in between. Flesh colour also seems to undergo continual variation, although less than skin colour does. Ocas have been seen with ivory-yellow and violet-purple flesh in several hues. There are a great many shapes in the vascular ring pigmented with the same colouring as the skin, followed in colour intensity by the medulla.

Oca collections in South America

Over the past ten years, expeditions have been made to Peru, Ecuador and Bolivia to collect cultivated oca. Field collections in Peru are being maintained and evaluated at the Universities of Cuzco, Huancayo, Ayacucho, Cajamarca and Puno, and at INIAA, where there are over 1 000 accessions with sufficient duplications. Most of this material is kept *in vitro* at the Biotechnological Laboratory of the Universidad Nacional Mayor San Marcos in Lima. The collection of Ecuadorian oca is kept as a field collection at the Santa Catalina station in Quito.

Cultivation practices

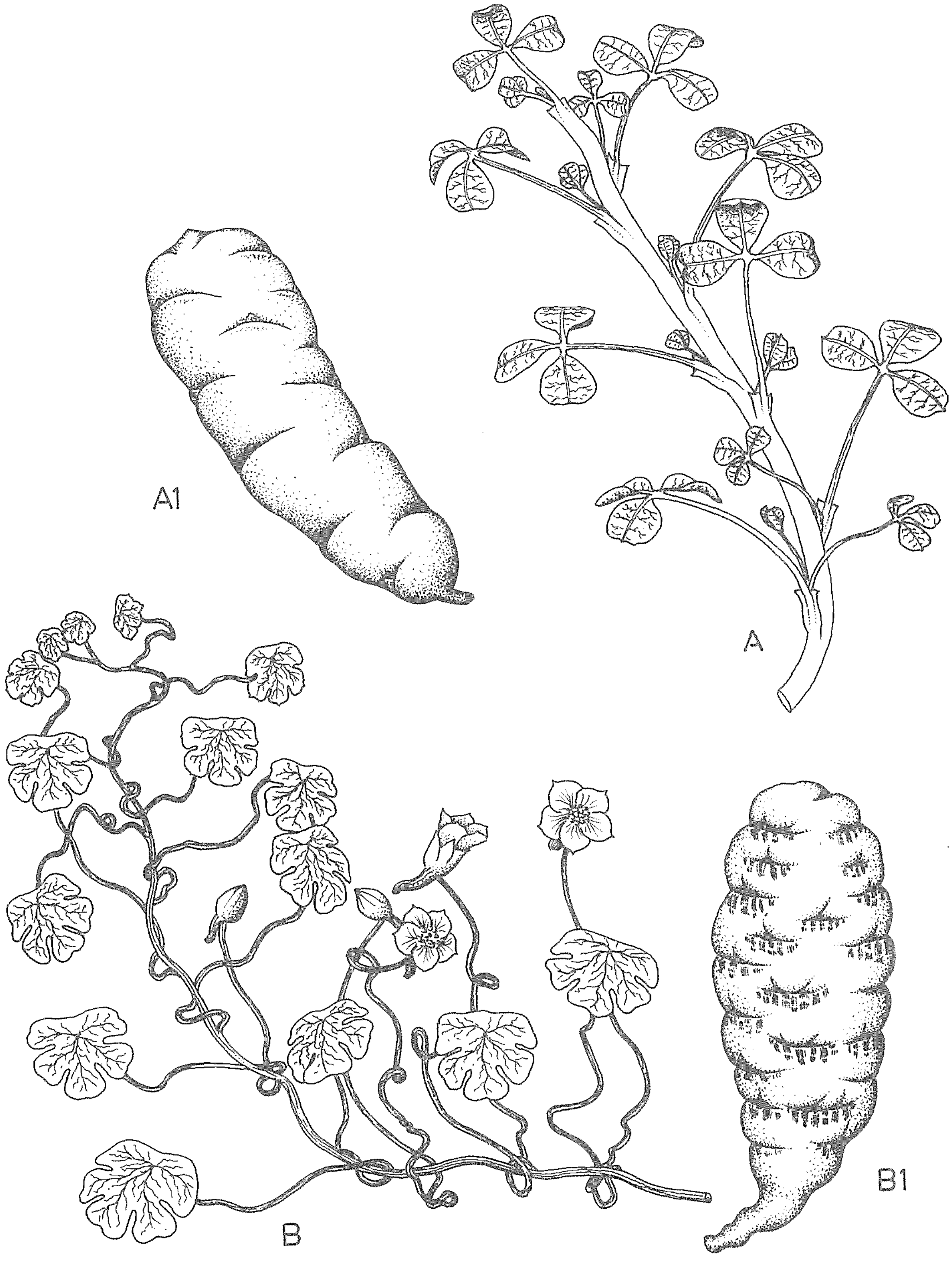
The three Andean tubers (oca, mashwa and ullucu) are grown in the same agro-ecological zone and their soil requirements and cultivation practices are very similar to those of the potato; for this reason they are dealt with together.

In the northern area of the Peruvian sierra, the traditional form of cultivation is on *melgas*: after cultivation of the potato, the land is divided into three to five plots, each of which is sown with one of the Andean tubers.

On the high plateau of Puno and in the agro-ecological zone of the semi-humid puna, a mixture of tubers is sown. By contrast, in the quechua agro-ecological zone, the oca and ullucu are planted together with maize. These crops show a high response to agricultural work such as fertilization, earthing up, hoeing and, above all, the control of pests and diseases; their production increases to levels of 40 to 50 tonnes per hectare, which are comparable to the highest potato yields.

FIGURE 15

Andean tubers: A) oca (*Oxalis tuberosa*); A1) tuber; B) mashwa (*Tropaeolum tuberosum*); B1) tuber



Prospects for improvement

The prospects for this crop lie in the possibility of increasing its yield and in its use as an alternative source of flour to wheat.

The following aspects should be taken into account:

- The oca has to compete for ground (cultivation areas) with potatoes; as a result, its expansion could be limited; research carried out in southern Peru seems to confirm this.
- Attacks by pests, such as weevils, may cause the loss of an entire crop; studies on the integrated control of these pests, through cultivation practices, biological control using the fungus *Beauveriabrogniartii*, post-harvest management and the use of resistant varieties would need to be carried out; bitter ocas show a degree of resistance to the various weevils.
- *Presence of viral diseases:* Although just one virus has been identified in the oca, it seems that others exist which damage the crop; the purity of commercial varieties and genetic materials must be established as standard practice, as virus-free varieties would give higher yields.
- The extensive growing period of seven to eight months exposes the crop for a longer time to attack from biotic and abiotic factors, and oca cultivation is consequently being gradually replaced by early varieties of potato (with a growing period of four to five months); the short duration of the tuber also affects its propagation.

The high yields in dry matter obtained from this crop and the possibilities of attaining up to 6 or 7 tonnes of flour per hectare are factors that ought to be dealt with in an agro-industrial research programme.

MASHWA
(*Tropaeolum tuberosum*)

Botanical name: *Tropaeolum tuberosum* Ruíz & Pavón

Family: Tropeolaceae

Common names. *English:* mashwa; *Spanish:* mashwa, mashua (Peru, Ecuador), isaño, añu (Peru, Bolivia), maswallo, mazuko, mascho (Peru) and cubio (Colombia)

Tropaeolum tuberosum apparently originates from the central Andes (lat. 10° to 20°S). Its cultivation is thought to have been spread by pre-Columbian migrations to Colombia (lat. 8°N) and northern Argentina and Chile (lat. 25°S). In spite of its hardiness, there are no references to its introduction into other countries, possibly because the tuber's flavour is not very pleasant when eaten for the first time.

Grown together with ullucu, oca and native potatoes on plots from approximately 30 to 1 000 m^2, it is difficult to ascertain its cultivated area and production. However, it is estimated that around 6 000 ha are sown annually in Peru, with an average yield of 4 to 12 tonnes per hectare. Under experimental conditions, up to 70 tonnes per hectare have been obtained.

From an agronomic point of view, mashwa is very hardy because it grows on poor soil, without the use of fertilizers and pesticides. Even under these conditions, its yield can be double that of the potato. Its cultivation together with ullucu, oca and native potatoes could be accounted for by the nematicide and insecticide control properties that the plant has.

Since the time of the Incas, who included them in their soldiers' rations, the tubers have had anaphrodisiac properties attributed to them. Today, it is known that testosterone levels are significantly reduced in male rats that are fed mashwa.

Uses and nutritional value

Mashwa is important for meeting the food requirements of resource-poor people in marginal rural areas of the high Andes. It is prepared in the form of a stew, as a roast or in the form of *thayacha*. For the latter preparation, the tubers are exposed overnight to frost and are eaten the following day accompanied by sugar-cane syrup.

Botanical description

T. tuberosum is an annual herbaceous plant of erect growth when it is young and it has prostrate stems with compact foliage when mature. This enables it to compete advantageously with weeds. At first sight, the tubers may be confused with oca tubers, but they can be distinguished by their conical shape, dark markings and a greater concentration of buds on the distal part, as well as by their sour taste.

The growing cycle of this species varies between 220 and 245 days. Unlike oca and ullucu, mashwa produces a great quantity of viable seeds.

Ecology and phytogeography

Mashwa is cultivated from Colombia to Bolivia, from 3 000 to 4 000 m, with a greater concentration between 3 500 and 3 800 m. In spite of the poor-quality soils, extreme temperatures, radiation, variation in precipitation and the winds of the Andes, the plant grows quickly, managing to repel insects and nematodes, suppress weeds and maximize photosynthesis. The proportion of dry matter transferred to the tubers can be as high as 75 percent.

Genetic diversity

The genus *Tropaeolum* has a wide geographical distribution and seems to be very variable. There are an estimated 50 species in Mexico and Central and South America. Wild species of mashwa in Peru can be found on the low ridges of the Peruvian coast, on the edges of forests or growing sympatrically with cultivated mashwa in the Andes.

Ornamental *Tropaeolum* can be found in gardens on the coast and in the Andes. Weed forms of mashwa, called kita añu, are sporadic in the maize or tuber fields of the sierra. *T. edule, T. polyphyllum* and *T. patagonicum* have also been described as producers of tubers in the Andes of Chile and Argentina, but they apparently have no economic use.

As in the case of the oca, the crossability groups are not known, in other words the situation of the mashwa's gene stock is unknown.

Chromosome calculations have established the basic number as $x = 13$. Cultivated forms are clearly tetraploid ($2n = 4x = 52$). The frequency of diploids, triploids and tetraploids is not known and nor is the possible gene flow.

Cross-pollination and the tendency towards self-fertilization, together with aesthetic selection, must have influenced the appearance of various morphotypes. It can be said that the diversity of the mashwa is less than that of the oca, and slightly less than that of the ullucu. However, variation has been found in tuber colour, shapes, bud characteristics and flesh colour. The tuber's skin colour varies from ivory to very dark-purplish violet, with several hues of yellow, orange and purplish violet in between. Pink or purple speckles or stripes may occur on the skin at the apex and under the buds. Tuberization in the buds is more frequent in clones of shortened conical tubers than elongated and ellipsoid conical tubers. The greatest variation in tuber colours and shapes is found in the region between central Peru and northern Bolivia.

Mashwa collections in South America

Cultivated mashwa, just like ullucu and oca, has been collected extensively in Peru, Ecuador and

Bolivia during the last ten years. The field collections of Peru, stored and evaluated in the gene banks of Ayacucho, Cajamarca, Huancayo, Cuzco and Puno, exceed 300 accessions. Many of the accessions are kept *in vitro* in the biotechnological laboratory of the Universidad Nacional Mayor San Marcos in Lima. The field collection of Ecuadorian mashwa is stored and evaluated at the Santa Catalina experimental station in Quito.

Cultivation practices

Mashwa cultivation practices are the same as those described for the oca [see p. 150].

Prospects for improvement

Because of its flavour, the mashwa could have a better chance of more extensive use in animal feeding. In this connection, certain clones with a protein content of up to 11 percent show good prospects.

An investigation into the factors limiting mashwa production, carried out by the CIP in the Peruvian Department of Cuzco (1989), elicited the following answers from the peasants: scarcity of suitable land (28 percent); low crop yields (17 percent); and scarcity of seed (17 percent).

The rise in population and consequent pressure on the land would seem to be a limiting factor not only in Cuzco but also in other parts of the Andes. Low crop yields would not be a serious limiting factor, since the mashwa responds well to good soil management. Seed scarcity is a problem that can be solved.

The main lines of research are as follows:

- the function of undesirable substances;
- the long cultivation period;
- tuber storage;
- the selection of varieties for the various agro-ecological conditions;
- consumption patterns in rural and urban populations.

BITTER POTATOES (*Solanum* x *juzepczukii*), (*Solanum* x *curtilobum*)

Botanical names: *Solanum* × *juzepczukii*, *Solanum* × *curtilobum*
Family: Solanaceae
Common names. *English:* bitter potato; *Aymara:* luki; *Quechua:* ruku; *Spanish:* choquepito, ococuri

It seems that the domestication of bitter potatoes began some 8 000 years ago and that, as cultivated domesticated species, they have been used extensively for at least 3 000 years.

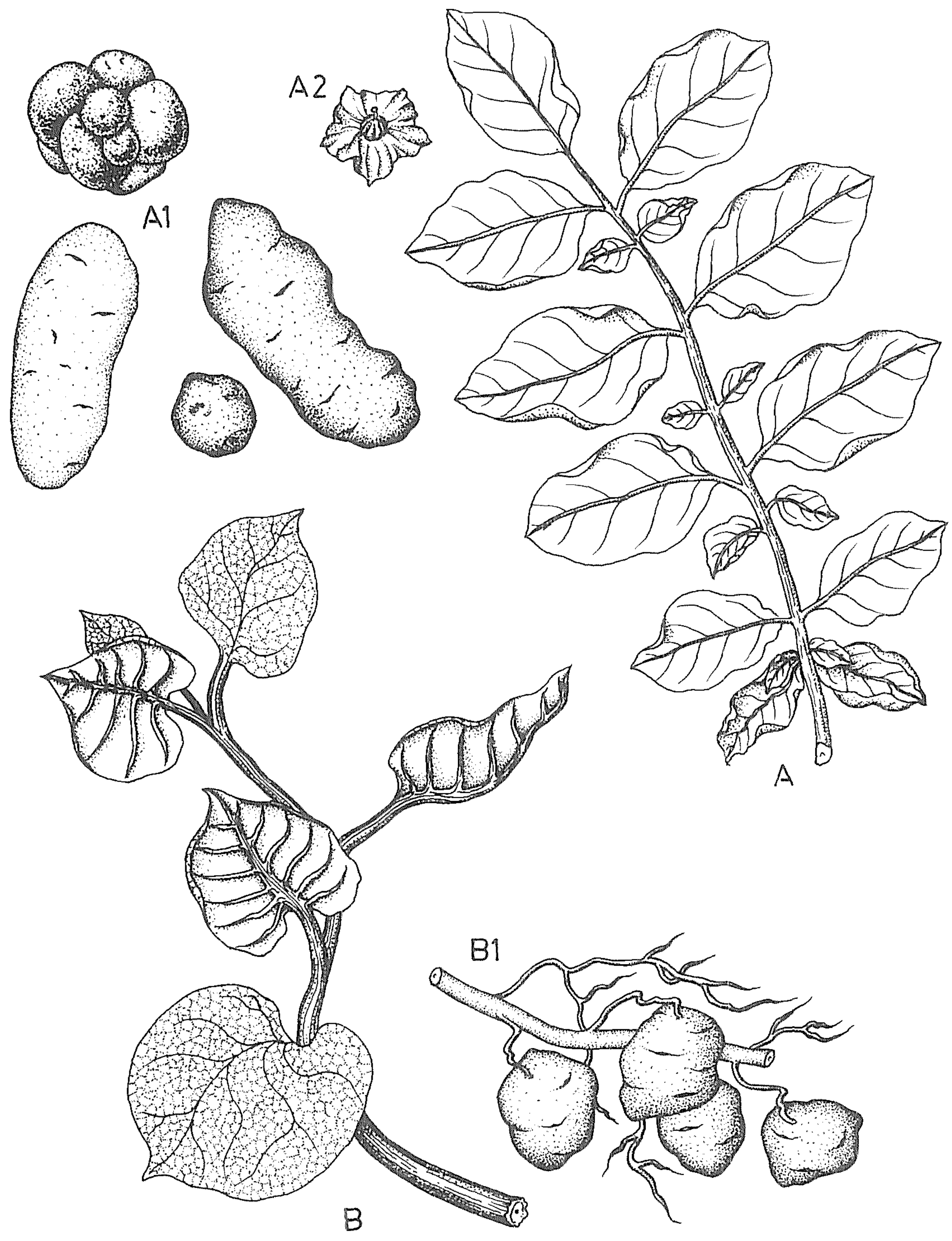
Acosta, one of the first Spanish chroniclers to describe the agricultural resources of the Andes, mentions that bitter potatoes that had been exposed to the cold overnight and then pressed and dried were transformed into what was known as *chuño* and were used as bread is in Europe. A century later, the priest Bernabé Cobo reported that, on the high plateau, there were wild potatoes and bitter potatoes which the Aymaras called aphus and which could only be eaten when processed as *chuño*; this food constituted the main staple in the high plateau region between Peru and Bolivia.

In spite of their importance for the agro-ecological zones of the puna, where frosts during the growth period limit food production, these crops were not studied during the time of the settlement, nor at the start of the Republic. During the 1920s, the Russian expedition organized by Vavilov and undertaken with his students Juzepczuki and Bukasov made a detailed description of these species on the basis of collections gathered on the high plateau around Lake Titicaca.

Several studies have been carried out on bitter potatoes during the past 50 years, including their origin, description and an evaluation of their nutritional capacity.

FIGURE 16

Andean tubers: A) bitter potatoes; A1) tubers; A2) flower; B) ullucu (*Ullucus tuberosus*); B1) tubers



The area cultivated at present varies greatly from one year to the next, depending on whether an adequate amount of seed is available. However, there are an estimated 15 000 ha in Peru and around 10 000 ha on the high plateau of Bolivia, on peasants' plots ranging from 300 to 500 m^2 and over more extensive areas on land under sectoral rotation. There are further potential areas for cultivation, the inclusion of which could easily double the current production.

Uses and nutritional value

If bitter potatoes are to be eaten, they must first undergo processing to remove the glycoalkaloids. Traditional processes in the upper Andean area, described in various works, consist of exposing the tubers to several night frosts and drying them in strong sunlight at altitudes of 4 000 m to obtain black *chuño*. Larger bitter potatoes are preferably used to prepare white *chuño*, also called *tunta* (Aymara) or *moraya* (Quechua). Freezing is followed by the peeling, hydrating for up to 30 days and drying.

Black *chuño* is produced up to the edge of the forest where it keeps very well because of its characteristics as a dehydrated product. White *chuño* is preferably eaten on feast days. It fetches a high price at town markets where it is an ingredient of various regional dishes. Both white *chuño* and black *chuño* are very rich in energy.

The potential of bitter potatoes lies precisely in their ability to withstand low temperatures and yield a surplus, thus constituting an important food reserve. It has been calculated that, between August and March, black *chuño* can account for 70 percent of the food of rural populations of the Peruvian and Bolivian high plateau.

Botanical description

Solanum × *juzepczukii* measures 30 to 50 cm and has a semi-rosette growth habit, long, straight leaves, short petioles and a small, blue corolla.

S. × *curtilobum* is distinguished by its more coriaceous leaves and its corolla, which is bigger and purple with very short lobules and a pointed end.

The tubers vary in size and shape, ranging from rounded (Piñaza) to elliptical, oblong or elongated-oblong (Luki), and in colour. Clones of Ococuri have purple and white tubers.

The growing cycle varies greatly between five and eight months. The clone Piñaza is one of the earliest, taking 150 days; Ruki clones are the latest, taking up to 195 days.

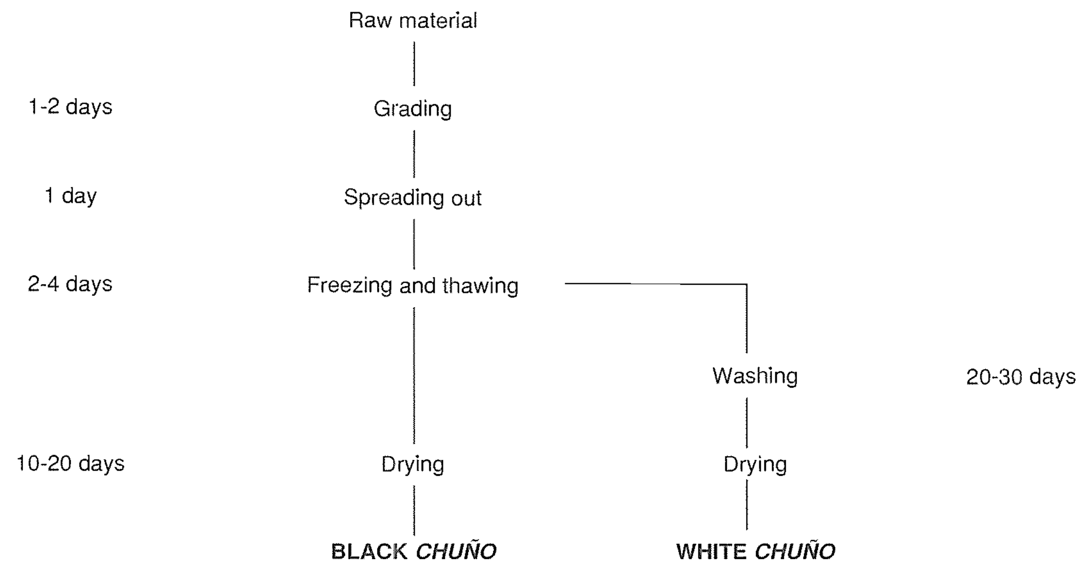
Ecology and phytogeography

Bitter potatoes are cultivated at altitudes between 3 000 and 4 300 m, in the agro-ecological zones of the humid puna and suni, which are characterized by mean growth period temperatures of between 6 and 14°C, with precipitations which vary according to the region and year between 400 and 1 400 mm, are spread over five to six months and which coincide with the summer period in the Southern Hemisphere (October-May).

Frosts may occur during the growth stage, with the temperature dropping to -5°C in some years. A greater incidence of low temperatures is observed in the dry period and these affect production heavily, with damage varying according to the species. Recently, in an area of Peru with frosts and temperatures of -5°C, the reduction in the harvest was 5 percent in the case of *S.* × *juzepczukii*, 30 percent in the case of *S.* × *curtilobum* and 40 percent in the case of the common potato.

The cultivation of bitter potatoes requires soils which have sufficient organic matter (3 to 5 percent) and which have had a period of fallow or adequate rotation. The best yields are obtained on soils which have lain fallow for three to four years and have had 2 to 3 tonnes of manure applied.

FIGURE 17
Diagram of *chuño* processing



Bitter potatoes predominate on land where the main production is livestock and where there is natural pasture and thus little pressure on the land. Because of this, land can be put under a rotational system of crops with canihua (*Chenopodium pallidicaule*) or fodder plants such as barley or oats, including a prolonged period (up to six years) of fallow during which the natural vegetation covers the soil again. In areas which have a very broken topography and where the puna zone is very close to the suni or quechua (valley) zones, rotation includes other crops suited to these conditions, with tubers such as oca (*Oxalis tuberosa*) and ullucu (*Ullucus tuberosus*) or mixtures of these species.

Genetic diversity

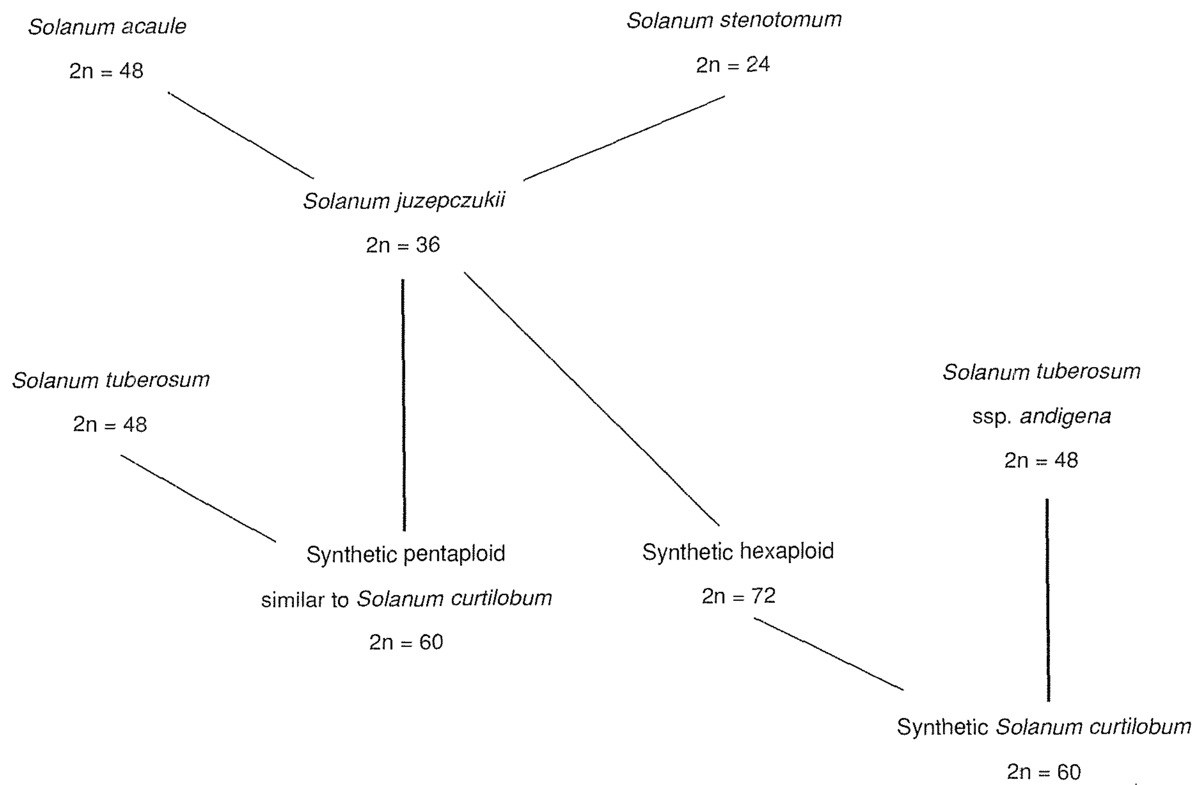
In the southern region of Peru and on the Bolivian high plateau, there are a great number of varieties which have been bred by the peasants over centuries and which are suited to various ecological conditions in the highest region of the Andes. Bitter potatoes belong to two species: *S.* × *juzepczukii* triploids and *S.* × *curtilobum* pentaploids. Because of their ploidy, which is caused by a high degree of sterility, it is difficult to use the characteristics of bitter potatoes in improvement programmes. The origin of bitter potatoes would seem to be due to various crossings derived from wild species such as *S. acaule*.

There is greater variability in the species *S.* × *juzepczukii*, the main cultivated varieties being Ruki, Luki, Piñaza, Parina, Locka, Parko, Keta and Kaisallu, with white or purple tubers.

In the species *S.* × *curtilobum*, we may distinguish those of the Choquepito group and the so-called Ococuri, which are characterized by a lower glycoalkaloid content than *S.* × *juzepczukii*.

There is an extensive collection of bitter potatoes in Cuzco and Puno in southern Peru, while a collection from the Bolivian high plateau is maintained at the experimental station of Patacamaya.

FIGURE 18
The origin of bitter potatoes



Cultivation practices

The soil is generally prepared with local implements, such as the *chakitaklla* or foot-plough, with the entire peasant family taking part in the operation, since it involves plots located in isolated places.

The sowing period of bitter potatoes is very much conditioned by the presence of rain, since the cap is grown under rain-fed conditions. The period extends from September to November, depending on whether the rains begin early or late, the tradition being to stagger sowing on two or three dates as a means of reducing the climatic risk. The crop needs to be earthed up once or twice when the plants reach a height of 20 to 30 cm. The start of tuberization coincides with the start of flowering, approximately seven to nine weeks after emergence, and lasts for about four weeks, during which time the absence of humidity and severe frosts is vitally important. In this respect there is a differentiation between early, intermediate and late ecotypes, which may mature between four to six months, hence a wide range is available for improvement programmes.

Fertilization is limited to sheep manure. However, there have been positive responses to the addition of chemical fertilizers in intermediate doses. The var. Piñaza responds better to fertilization than the var. Ruki, but the latter has a higher dry matter content.

The varieties of *S.* × *juzepczukii* are better suited to shallow soils than *S.* × *curtilobum*, which has deeper roots.

On account of their prostrate habit, bitter potatoes are susceptible to nematodes (*Naccobus aberrans*), to the Andean weevil (*Premnotrypes* spp.) and also to wart fungus (*Synchytrium endobioticum*).

Prospects for improvement

The tolerance of bitter potatoes to low temperatures is considered to be their main advantage and there is considerable scope for making selections from current populations. The existence of several varieties also enables cultivation to be extended to the different soil conditions in the highest area of the Andes. Bitter potato genes have been used more for the improvement of so-called sweet varieties than for their own improvement.

The main limitation is their glycoalkaloid content which gives them a bitter taste. In addition to solanine and chaconine, this includes tomatine, mysine and solamargine. However, since there is wide variability in this characteristic, varieties with a low content of this chemical substance can be selected. Although the current process to remove the bitter taste is fairly suited to local conditions and utilizes the climatic characteristics of the puna effectively, with its severe night frosts and intense daytime solar radiation, it is very labour-intensive (working conditions are very hard): it takes between 14 and 28 days to produce white *chuño*.

ULLUCU
(*Ullucus tuberosus*)

Botanical name: *Ullucus tuberosus* Loz.
Family: Basellaceae
Common names. English: ullucu, oca quina; *Quechua:* ulluku, ullus; *Aymara:* ulluma, illako; *Spanish:* michurui, michuri, miguri, micuche, ruba, rubia, timbo, tiquiño (Venezuela), chigua, chugua, rubas, hubas, camarones de tierra (Colombia), melloco (Ecuador), olluco, ulluco, lisa, papalisa (Peru), lisa, papalisa (Bolivia) and olloco, ulluca, ulluma (Argentina)

The ullucu is a plant native to the Andes. Ancient in origin, it is likely that its cultivation extended from the Andes of Venezuela (lat. 10°N) to northwestern Argentina and northeastern Chile (lat. 25°S) in pre-Hispanic times. However, the exact region of its domestication is not known. Ceremonial vessels of the Robles Moqo style of the Wari culture (the centre of which was Ayacucho between AD 400 and 700) are decorated with multicoloured representations of Andean plants, including the ullucu. It also appears on *qero* ceremonial vessels of the post-Incan era. The oldest vestige is the presence of starch among 4 000-year-old plant remains from Ancón and Chilca on the Peruvian coast.

The ullucu's wide distribution in the Andes and its age are also revealed in the profusion of regional names.

Uses and nutritional value

Of the three Andean tubers, the ullucu is the most popular and has become established on the tables of both the rural and urban population in Ecuador, Peru and Bolivia. Traditional preparations include *mellocos* soup (Ecuador); *olluquito con charqui* (ullucu with meat – Peru); *chupe* (potato, meat, egg and cheese stew) and *ají de papalisas* (ullucu pepper – Bolivia and Peru). It is also suitable for use in contemporary dishes such as salads. Some varieties contain a greater quantity of mucilage and need to be preboiled before preparation to remove it. The Andean tubers perish easily, which explains why ancient Andean peoples attempted to store surpluses by freezing and drying, processes used also for the ullucu. The product obtained is called *lingli* in Peru; its average protein content is 1.7 percent in the edible tuber, while the carbohydrate and energy content is slightly less than that of most tubers.

Botanical description

The ullucu is an erect, compact plant which reaches a height of 20 to 50 cm. At the end of its growth it is prostrate. Tuber shapes vary from spherical to cylindrical and colours range from white, yellow, light green, pink and orange to purple. On very rare occasions, it forms fruit; the seed then has the form of an inverted pyramid, with very prominent angles and a corrugated surface.

Ecology and phytogeography

The origin and development of the ullucu in the cold climates of the Andes suggest that it is one of the crops most suited to the complex agro-ecology of areas between 3 000 and 4 000 m. Although the precise role of hybridization, introgression and mutation in the ullucu is not known, these must have acted – along with natural and human selection pressure – to favour the plant's distribution and adaptation to the various types of Andean climate and soils.

Genetic diversity

The wild ullucu would seem to indicate a sympatric distribution with the cultivated ullucu, since up to now it has been found from the Andes of La Libertad in Peru (lat. 8°S) to northwestern Argentina (lat. 25°S). This would appear to indicate a smaller geographical range of habitats than that of the cultivated ullucu. However, collecting expeditions have been orientated towards cultivated material, which is harvested in dry periods when there is no opportunity to collect wild material. It is probable that in the geographical distribution area of the wild ullucu – which seems to be wide – ullucus may be found with interesting characteristics that will help to extend our knowledge of its domestication.

Cultivated ullucus are diploid and triploid, with a basic number of 12. The presence of polyploids in the wild ullucu has also been demonstrated. Nevertheless, the frequency of diploids, triploids and probably tetraploids needs to be determined. In the wild, triploids are generally formed by hybridization between diploids and tetraploids, or by the fusion of a normal gamete and another that has not been reduced between diploid parents. Triploids are generally sterile and the only way of propagating them is vegetatively. Their great vigour allows them to prosper and occur in profusion over a wide distribution area.

The study of meiosis in the cultivated diploid ullucu shows a regular meiotic pairing with the formation of 12 bivalents. Meiosis of the triploids is within expectations, i.e. defective and with the presence of univalents and trivalents. Meiotic pairing of artificial diploid hybrids would need to be researched, provided the combinations are possible.

Ullucu collections in South America

Cultivated and wild ullucus did not arouse much interest among plant explorers in the past. In spite of the fact that the collections of Bukasov and Juzepczuki in South America between 1925 and 1928 were followed by several expeditions to gather cultivated and wild plants, ullucu does not seem to have been collected, even within the same South American countries. Three stages could be distinguished in the collection of ullucu and the formation of gene banks. The first occurred in the 1920s with the work of Bukasov and Juzepczuki; the second covers the work of León through the establishment of the then greater collection of ullucu germplasm at the IICA, with material from Colombia, Ecuador, Peru and Bolivia. Later, collections of wild ullucus were made in northeastern Argentina and Bolivia by Brucher. The third stage began in the 1970s with small local collections at the Universities of Cuzco, Huancayo and Ayacucho, and likewise in the 1980s. Thanks to very positive help from the IBPGR, FAO, CIID and IICA/OAS they were continued more intensively with national programmes such as those of the IBTA in Bolivia, INIAP in Ecuador and INIAA and the Universities of Puno, Cuzco and Ayacucho in Peru. Under these programmes, gene banks are produced annually. These banks suffer from the following shortages which limit the knowledge and promotion of the ullucu:

- *Scant geographical representation:* While the Andes of Ecuador and Peru were explored, few or no collections were made in the Andes of Colombia, Venezuela, the eastern area of Peru, southern Bolivia and northwestern Argentina.
- *Duplication of accessions:* In clonal propagation crops such as the ullucu, there is a high probability of repeatedly collecting one and the same clone in different localities; also, the exchange of germplasm between national programmes without identifying data has meant that one and the same clone can be recorded under different numbers in various banks.
- *Incomplete documentation:* No standardized, internationally accepted descriptors exist for the characterization of the ullucu; there is a lack of specimens from herbaria – such information would be very useful in the event of living collections being lost.
- *A lack of wild plant collections:* There is an almost total absence of wild material; such material would help to understand the variation patterns of the cultivated forms and could provide valuable characteristics for improvement.

Cultivation practices

Ullucu cultivtion practices are the same as those described for the oca [see p. 150].

Prospects for improvement

Although the ullucu is a hardy plant that is suited to the difficult conditions of the Andes, viral diseases seem to constitute one of its most serious problems. Viral infections in gene banks affect up to 80 percent of samples. This is a particularly serious problem, not only for gene banks, but also for the crop's management.

Viruses may form viral complexes of up to four different particles in a single plant, causing loss of vigour, deformation and leaf mottling. Moreover, they are far more difficult to eliminate than bacterial or fungal pathogens. Eradication in commercial varieties and selected genetic material is an urgent requirement, although the number of viruses which affect the ullucu is not known. Studies at the CIP have revealed at least four viruses, but the number may be higher.

Another limiting factor is the prolonged cultivation period. While modern commercial varieties of potato are harvested after four or five months in the Andes, the ullucu takes seven or eight months to mature. In other words, ullucu plants are exposed longer to drought, frost, pests, diseases and other adverse factors which are frequent in the Andes. Productivity in terms of time and space is consequently low. It seems to be one of the causes of marginalization, so that ullucu cultivation is gradually being replaced by varieties of early high-yielding potatoes.

The biggest advantage of the ullucu is that it is firmly established among rural and urban people in areas where its supply is almost continuous throughout the year.

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Andean roots

MACA
(*Lepidium meyenii*)

Botanical name: *Lepidium meyenii* Walp.
Family: Brassicaceae (Cruciferae)
Common name. *English:* maca, pepper grass, pepper weed; *Spanish:* maca (Peru)

The maca is one of the Andean crops which occupy a very restricted area. It is found only on the central sierra of Peru in the departments of Junín and Pasco, in the puna agro-ecological zone above 4 000 m where low temperatures and strong winds limit other crops.

Domestication of this plant appears to have started at least 2 000 years ago, around the area of San Blas in the department of Junín. During his visit to the Junín area in 1549, the *encomendero* Juan Tello de Soto Mayor reportedly received maca "fruits" as a tribute and used them to improve the fertility of the livestock of Castile. It was also stated, during a visit to the area of Huánuco in 1572, that the Chinchaycochas had used the maca for bartering since the time of the Incas, as there was no other crop on their lands.

The maca is grown on small plots with a few rows and up to about 500 m^2 in size, on peasant land in communities around Lake Junín (Yanacancha, Ingahuasi, Cerro de Pasco, Ninacaca and Vicco). It is a biennial herbaceous plant, whose subterranean part (hypocotyl) is edible and highly valued for its nutritional value, especially proteins and minerals. The rural community is firmly convinced that eating maca enables couples who think they are infertile to have children.

The author of this chapter is J. Rea (La Paz, Bolivia).

Uses and nutritional value

When the fresh hypocotyls have been harvested, the peasant usually roasts them in the field in the form of *huatias* (cooked between clods of red-hot peat) on *pachamancas* (cooked in contact with hot stones taken from a wood fire and covered with earth). However, most of the harvest is left to dry and can then be kept for several years.

For eating purposes, the dried hypocotyls are hydrated overnight and parboiled in water until they are soft. They can be liquefied to prepare juices, cocktails, porridges and jams. Nowadays the dry matter is being processed to prepare products in tabloid form which are in demand because of their nutritional value and because of the supposition that they stimulate sexual appetite and increase fertility.

The high calcium content (258 mg) and iron content (15.4 mg) per 100 g are the main advantages of this Andean crop. It has a 14 percent protein and 78 percent carbohydrate content and is also rich in starch, glucosides, alkaloids and tannins. The protein content may vary between 10 and 14 percent depending on the fertility conditions of the soil and the variety.

Rats fed on maca produced some 25 percent more offspring than control rats, probably because development of the Graafian follicles is stimulated.

Botanical description

Lepidium meyenii is a herbaceous, perennial plant, growing 12 to 20 cm. Its has succulent roots and short and decumbent stems. Its leaves are rosulate, pinnatipartite and are continuously renewed from the centre of the rosette. The racemes are pauciflorous. The fruit is in siliculae, measures 4 to 5 mm and is dehiscent with two carinated valves, each containing a seed. The seeds are ovoid, 2 to 2.5 mm and reddish grey.

The hypocotyls, which are the edible part of the plant, vary between 2 and 5 cm in size and may be white or yellow, reddish and white, white and yellow, white and purple, light-lead grey, purple and lead grey or yellow, red and grey.

Ecology and phytogeography

Cultivation of the maca is limited to the puna agro-ecological zone of the central region of the Peruvian Andes, at altitudes between 4 000 and 4 400 m. The puna is characterized by periods of temperatures below 0°C, called frosts, even at the height of the crops' growing period. However, the maca tolerates these temperatures fairly well, just as the bitter potato does. When the maca was sown in other latitudes, such as in Berlin, Germany, (lat. 52°N) in 1990, it did not manage to form hypocotyls. This result appears to support the idea that the maca is a short-day plant.

Genetic diversity

The species *L. meyenii* was described by Gerhard Walpers in 1843. It has been suggested that the cultivated maca is not *L. meyenii* but a new species, *L. peruvianum* Chacón, based on various specimens collected since 1960 in the district of San Juan de la Jarpa, in Huancayo province. This assertion is based on comparative studies of the botanical characteristics, and in particular on the histochemical observations of the hypocotyl, which is the main distinguishing feature of this new species.

In the cultivation area, at least eight types of maca are differentiated according to the colouring of the plant and the hypocotyl. Although there is no gene bank for this species, the Agricultural University of La Molina and the University of Pasco have collected genetic material.

Cultivation practices

The maca is sown at the beginning of the rainy period (September-November) as the sole crop or combined with strips of bitter potato. According to the peasants in the area, this combination protects the potato from insect attack, since the maca contains repellent volatile substances.

It can be sown on freshly ploughed pasture land that has lain fallow (*purun*), or on ground under an annual rotation with another crop (*kallpar*) such as the bitter potato. Generally speaking, soil preparation is deficient and broadcast sowing is carried out without any fertilization or, at best, only a manure dressing. The seeds are buried using branches or are left to be trod on by sheep. Tillage is not usually carried out, except to make sure that the small plants are not trampled by animals. The maca is believed to deplete the soil; this probably occurs when the nutrients removed are not sufficiently replenished.

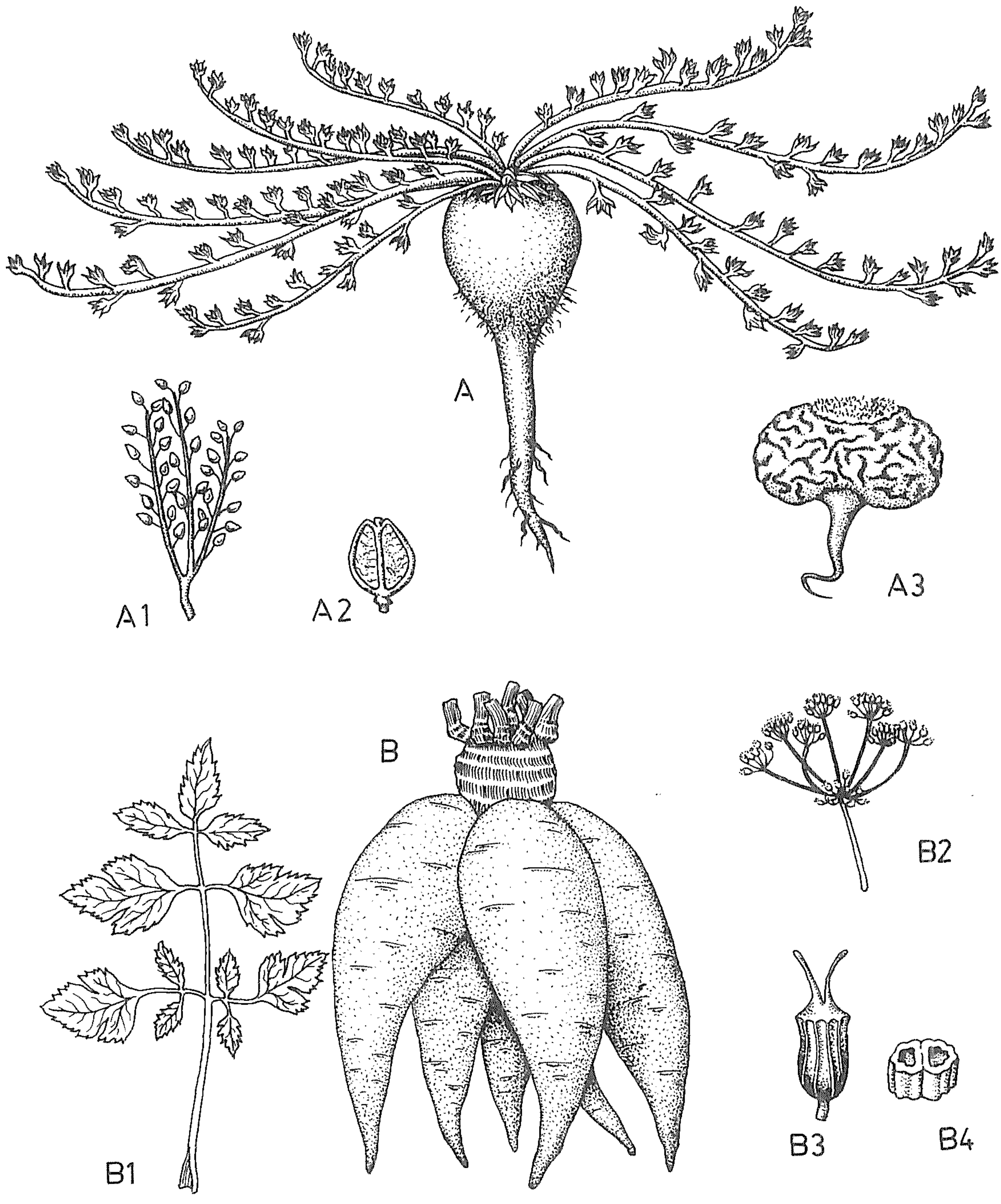
Harvesting begins in May or June. The fresh hypocotyls are exposed to the sun's rays for about four to six days until they are dry. They are then stored in a cool, dark place until they are eaten.

The yield is very variable: in fields where little care has been devoted to managing the crop, about 2 to 3 tonnes per hectare are obtained while, with appropriate row cultivation practices, fertilization and the prevention of pest attacks, it is possible to produce up to 15 to 16 tonnes per hectare.

Plants which produce the hypocotyl in the first year do not produce seed. The following practices are carried out to obtain seed: after selecting the biggest, soundly formed and suitably ripened hypocotyls, between 30 and 50 are placed in a hole which is 50 to 60 cm deep and of the same radius and which is covered with damp earth. The plantlets take 25 to 30 days to grow. To transfer them, a seed bed is prepared with soft earth and fertilized with farmyard manure. Care must be

FIGURE 19

Andean roots: A) maca (*Lepidium meyenii*); A1) racemose inflorescence; A2) fruit in a silicula; A3, dried root; B) arracacha (*Arracacia xanthorrhiza*); B1) leaves; B2) umbel inflorescence; B3) fruit; B4) cross-section of the fruit



taken to ensure that there is adequate humidity for the vigorous development of the plants, which will produce seeds within six to seven months after transplanting.

Prospects for improvement

This crop offers excellent possibilities for improvement, in particular because there is a potential market for the hypocotyls as a stimulant (similar to ginseng).

With simple mass selection techniques, varieties can be bred which give a better yield and are more uniform, thus facilitating their processing. Current local ecotypes have to be conserved so as not to lose existing genetic variability.

Cultivation practices can also be improved: a system of cultivation combined with the bitter potato is suggested, this being another species suited to the ecological conditions of the puna.

The main limitation, which is being overcome, has been the scant attention that producers (basically livestock farmers from the puna area) have paid to this species. In order to encourage its cultivation, a yearly maca fair has been held since the Association of Maca Producers was established in the department of Pasco some years ago.

ARRACACHA
(*Arracacia xanthorrhiza*)

Botanical name: *Arracacia xanthorrhiza* Bancroft

Family: Apiaceae (Umbelliferae)

Common names. English: arracacha, white carrot, Peruvian parsnip; *Aymara:* lakachu, lekachu; *Quechua:* oqqe, huiasampilla, laqachu, raqacha, virraca, rikacha; *Spanish:* arracacha, racacha, zanahoria blanca, apio criollo, sonarca; *Portuguese:* batata baroa, mandioquinha, batata salsa, batata cenoura; *French:* arracacha, panème, pomme de terre-céleri

This is possibly one of the oldest cultivated Andean plants, its domestication having preceded that of the potato. There are no vestiges whereby its area of origin can be identified, although it could have been the northern part of South America, in view of the presence there of related wild species. Outside the Andes, it is grown in the Antilles, Central America, Africa, Sri Lanka and in large commercial areas in southern Brazil, where it is industrialized.

The basic causes of its marginalization should be sought in the socio-economic context of its growers. The current secondary causes are to be found in a few limiting factors of an agronomic nature. We may mention its photoperiod requirements, susceptibility to extreme temperatures, long growth cycle, susceptibility to pests and diseases and the difficulty of storing its roots. These are factors which can be modified if agronomic improvement work is carried out.

Uses and nutritional value

In the Andean region, potatoes are scarce in town markets during years of drought or frosts in the high areas. They are replaced by the arracacha, cassava, sweet potato, tannia (*Xanthosoma sagittifolium*), cocoyam or dasheen (*Colocasia esculenta*) and yam beans (*Pachyrhizus* spp.).

The roots are harvested as from the fourth month, depending on the cultivar and region. They are eaten boiled or as an ingredient in soups and stews, and also as a purée, roasted and fried in slices. The leaves are prepared in the same way as celery in raw or cooked salads, hence the name "Creole celery" which is given to it in Venezuela. After two to three months of storage, the sugar content in the roots increases through partial conversion of the starches.

The stump or crown of the roots – containing approximately 9 percent protein – is used to feed dairy livestock. The plant's stem and leaves are likewise used as animal fodder while the dried leaves can be used to prepare meal, which is also used as animal feed.

The arracacha's pleasant flavour and easy digestibility, which are universally acknowledged, result from the complex of starches, oils and mineral salts. The starch content ranges between 10 and 25 percent. The seeds are fine and similar to those of cassava. The arracacha is a good source of minerals and vitamins.

Botanical description

The plant consists of a short, cylindrical stem which grows to a height of 10 cm and a diameter of 10 cm, with numerous buds on the upper part. Each of these has leaves with long petioles, divided into three to seven very jagged folioles. The leaves are green or bronze-coloured depending on the variety. Two kinds of roots emerge from the stem: long and fine ones or tuberous and fusiform ones. The latter are the usable part. They are 5 to 25 cm long and up to 8 cm in diameter. The root is harvested before the end of the growing cycle; if it is left, floriferous buds sprout from the stem. The inflorescences are composite umbels, bearing many small, deep-purple flowers, a calyx and a corolla of five minute parts. The fruit is bicarpellar with an inferior ovary.

Ecology and phytogeography

Arracacia xanthorrhiza's minimum humidity requirement is 600 mm and the optimum 1 000 to 1 200 mm. It grows at an altitude of between 1 500 and 3 000 m, depending on the latitude, and its optimum temperature is 14 to 21°C. Lower temperatures delay ripening of the roots and affect foliage growth. Higher temperatures, as in Maracay in Venezuela and Santa Marta in Colombia, and probably in the Amazon region, seem to reduce root size. *A. xanthorrhiza* grows in deep soils which have good organic matter, are fertile, well-drained and sandy, with a pH of 5 to 6. It does very well in fertile volcanic soils. Short days are required for good rooting.

The phytogeographical characteristics of the main cultivation regions are as follows:

In eastern Venezuela, better-quality arracachas, such as Amarilla, are produced at 1 200 to 1 400 m; in Barimitas, Santo Domingo, at 1 500 to 1 800 m. In Mérida, Venezuela, small crops of arracacha are found on the valley floors and on east-facing slopes. During dry periods, they are irrigated every two weeks. In Táchira, Venezuela, they are rotated with banana and plantains and are combined with maize through intercropping with maize and beans. In Colombia, *A. xanthorrhiza* occupies an important place in the production structure of departments, such as Ibaqué, that are above 1 800 m; in Antioquía, Río Negro and Nariño, between 1 200 and 2 800 m; and in the basin of the Otengá River in Boyacá, up to 3 200 m. On the coast, it grows in Santa Marta at 40 m. Under conditions of abundant humidity with irrigation, it is sown throughout the year and harvested at eight to 12 months.

In Ecuador, crops are found between 1 500 and 3 000 m along the inter-Andean passage, although there are fewer of them on the western and eastern sides of the range. At higher altitudes, it is cultivated sporadically; production cycles exceed one year, with greater development of the stump or crown in relation to the roots. The greatest concentration of cultivars is in Azuay and Loja.

In Peru, it is cultivated almost throughout the country from 1 200 to 3 200 m, where there is humidity. The two major centres of diversity are found in the northern sierra (Cajamarca) and southeastern sierra (Cuzco).

In Bolivia, the greatest concentration of crops is in the yungas of La Paz and Cochabamba, between 1 000 and 1 800 m. In the valleys of La Paz, cultivation is very sporadic, and is carried out at 3 500 m, with irrigation during dry years.

In Brazil, it has spread from São Paulo to Santa Catarina, where it is intensively cultivated from 700 to 2 000 m.

Genetic diversity

Among more than 60 specimens collected in the Andean countries, there are numerous cultivars which are differentiated by foliage colour and the external colour of the root: white or yellow, both with purple pigmentations.

Germplasm collections in South America

ICTA established a gene bank between 1965 and 1967, with 50 accessions from Colombia, Bolivia, Ecuador and Peru. The collection was kept in San Mateo in Lima but at 3 050 m but, because of the termination of the Andean Crops Programme, this material was transferred in 1967 and 1968 to various institutions in Andean countries and Brazil.

There are a great many varieties in Colombia: Paliverde is the most common (90 percent), Paliamarilla occurs to a lesser extent and Palirrusia or Palirroja are uncommon. Paliverde can attain yields of 10 to 15 tonnes per hectare of roots and 4 to 7 tonnes per hectare of stumps.

Considerable variability has been found among arracachas, particularly insofar as foliage and root characteristics are concerned. The most notable types are the bronze-foliaged ones originating from Colombia. In these, no correlation is observed between the presence of anthocyanin in the leaves and roots, since the latter had a white epidermis and also a white phloem and xylem. The types with yellow roots, both on the surface and on the internal part, have a pale bronze foliage, with anthocyanins restricted to the lower section of the leaves. Consequently, there is no clear correlation between foliage colour and root colouring.

The congeners closest to the cultivated species are: *A. sequatorialis*, *A. andina*, *A. elata* and *A. moschata*. Other species have also been found, such as *A. pennelli* Constance in Bogotá, *A. tolucensis* H.B.K. var. *multiflora* in Colombia and Mexico; *A. wigginessi* Constance in the south of Cuenca, Equador; *A. incisa* Wolf in La Oroya; and *A. peruviana* Wolf in Ayacucho, Peru.

Cultivation practices

The description of the traditional cultivation technique is based on experiments and visits made to peasants in Colombia and Peru.

The arracacha is reproduced by *colinos* (in Colombia), suckers or *pashincas* (in Peru), which are short ramifications or shoots which emerge from a *madre* in Colombia and a *buque* in Peru. In Colombia, approximately 400 kg per hectare of *colinos* are required which are planted out and then earthed up. When rooting has developed, three or four earthings can be done at the same time as weeding, although some farmers say that if earthing up is done repeatedly the plant produces only foliage. The growing period is variable; in the highest and coldest areas it can be eight months while, in the savannah, it can be as long as a year. This species prefers cloudy areas with a constant humidity.

In some areas, the arracacha is included in a rotation. It generally follows potatoes and vegetables or is combined with maize (five furrows of maize and one of arracacha) and also with coffee (in Manizales, Colombia). The sowing time coincides with the beginning of ripening of the maize and it is then left in the field for up to two years.

Prospects for improvement

The following may be mentioned as agronomic limitations of *A. xanthorrhiza*: its long production cycle compared with potatoes and other tubers; the lignification of its roots on maturity; the deterioration in the quality of stored roots; pests and diseases, such as one unidentified mite which attacks the roots; rotting caused by *Pseudomonas* sp., which begins at five or six months in the root and foliage; *Alternaria* sp., *Erwinia* spp. and *Rhyzoctonia crocorum*; and lesions from nematodes, such as *Pratylenchus penetrans* which cause root necrosis.

There is room for improvement in the present production system of peasant agriculture. An analysis of cultivation practices from sowing up to harvesting should be the basis for implementing future research depending on specific local situations.

In every country and in the regions with the greatest concentration of cultivations and germplasm, it would be of socio-economic, cultural and educational benefit to organize communal centres of action, where specific projects are put into operation as part of an integral concept whose economic feasibility is tested with the farmers themselves and neighbouring communities. For example, the operation of a processing unit would be linked with production, postharvest marketing and the industrial process. At the same time, school and community canteens could be run on the basis of educational and nutritional criteria. Any surpluses achieved during a project would reflect the satisfactory result and would make extension to other regions easier. Shared research on a wide scale needs to be planned with farmers on smallholdings. Covering a large area with multiple ecologies, projects would benefit from the contribution of many people. The positive aspects of existing farming practices would be reappraised and specific problems solved.

This genuinely revolutionary methodology is being tested in some Andean countries, where peasant communities are responsible for its administration. The real promoters, i.e. expert peasant farmers who share out the benefits, therefore participate in its operation.

This proposal is a departure from the schemes based on traditional technical standards and values and suggests a change in the logic and rationality of approaches. The theory seems to tie in with practice, as was the case for the Aymaras and other Andean peoples who constantly carried out practices and trials each year and for each crop, on one and on many smallholdings, thereby ensuring the survival of the population.

Potential areas for introduction and cultivation

The result of the research will make it possible to extend the current restricted frontiers of arracacha cultivation. For example, in Cajamarca in Peru and Anaime in Colombia, which are regions with an Andean ecology, it would be possible to step up cultivation with a view to industrialization, as is happening in southern Brazil.

Lines of research

Under INIAP's Andean Crops Programme (in Ecuador), the following strategies of action have been drawn up:

- completing the collection, evaluation and conservation of germplasm;
- identifying the plant health problems of the crop and the traditional techniques used among producers;
- evaluating protein variations in the cultivars;
- identifying consumer preferences and suggesting new forms of consumption;
- organizing small community undertakings for production, processing and marketing;
- carrying out work on the botanical, agronomic, phytosanitary and dietetic characterization and evaluation (including aminograms) of germplasm and crops;
- studying the plant's physiology, including the storage of roots, *colinos*, rootstalks and sexual seeds;
- promoting the production of sexual seed;

- studying photoperiods and thermoperiods, resistance to cold and drought, the effect of temperatures on growth and root yield.

MAUKA, CHAGO (*Mirabilis expansa*)

Botanical name: *Mirabilis expansa* Ruíz & Pavón
Family: Nyctaginaceae
Common names. Spanish: mauka (Bolivia), chago, arricón, yuca, inca, cushipe, chaco (Peru), miso, taso, pega pega (Ecuador)

The cultivation of *Mirabilis expansa* was first described 25 years ago in La Paz, Bolivia. Some 15 years later it was found to the north of Quito, Ecuador, and later in Cajamarca, Peru, where there seems to be the biggest area of production. It is an interesting case of a practically unknown crop with a wide geographical distribution – it is known from Venezuela to Chile.

The crop is maintained in small vegetable gardens and in a marginal way. It is greatly valued in the communities of temperate valleys at around 2 800 m for human consumption and animal feed. It occurs alone or combined with maize, curcurbits or other plants, and remains in the field for several years as a result of the transplanting of vegetative parts.

Uses and nutritional value

The roots and leaves are used for human consumption. It is prepared in the same way as sweet potato or cassava: shortly after harvesting, the root is parboiled and peeled, and it can also be an ingredient of soups and stews; the leaves are used in salads and chili sauces. In Ecuador, it is eaten as a savoury or as a sweet. For the latter preparation, it is buried for approximately one week in pits dug in the soil, where layers of barley straw and mauka are alternated so as to concentrate the sugars. In both cases, it can be accompanied by coarse sugar honey.

In Bolivia, the stems and swollen roots, which are yellow, are left to ripen in order to eliminate certain astringent constituents which might the affect the tongue and lips. They are then cut and cooked, preferably adding corn molasses, cane molasses or sugar to make them more agreeable. The cooking water is served as a soft drink.

The whole plant is used as animal feed and pigs, cavies, sheep and cattle are very partial to it. For pig feeding, the raw underground parts are mixed with the foliage, wild vegetation or maize while cavies are fed the green foliage or hay. Its degree of conversion is higher than that of other agricultural by-products.

Dietary analyses of Bolivian maukas showed a 7 percent protein content, 2 760 mg of calcium and 590 mg of phosphorus (in dry matter) in the underground parts and a 17 percent protein content in the foliage.

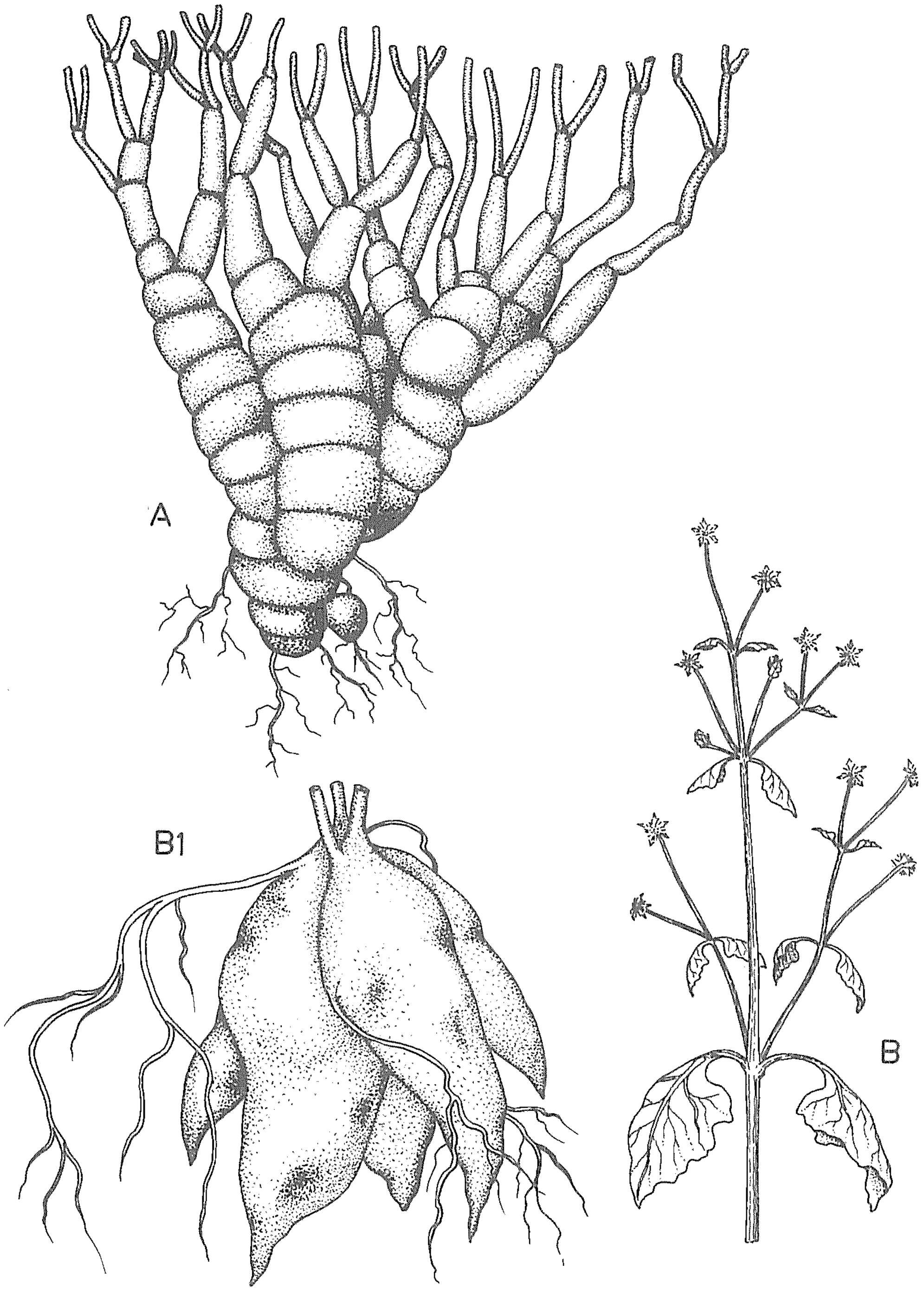
Analysis of three cultivars of chago (mauka) from Cajamarca in Peru gives between 4 and 5 percent protein. The calcium content is very variable with a minimum of 157 mg and a maximum of 461 mg. The phosphorus content is 117 mg per 100 g. It is low in sodium and iron. The protein, calcium and phosphorus content of the chago is higher than other roots and tubers grown in the same agro-ecological area. This is an important advantage if we consider that the diet of the high Andes is frequently deficient in calcium and phosphorus. Because of its low sodium content, the chago could be promising in low-sodium diets.

Botanical description

A low, compact plant, *M. expansa* grows up to 1 m in height. The swelling of the edible part of the collar would tally with a perennial plant. The aerial part is formed by the branching of basal shoots from which dense groups of leaves arise.

FIGURE 20

Andean roots: A) mauka, chago (*Mirabilis expansa*); B) leafcup (*Polymnia sonchifolia*); B1) roots



The stems are cylindrical and are divided by nodes, from which pairs of opposite leaves arise. The leaves are ovulate or cordate, 3 to 8 cm long, 2 cm wide and somewhat coriaceous. The nervures and edges have reddish areas. The inflorescences are on long, slender terminal branches, are 3 to 6 cm in length and are covered with hairs which frequently have small insects stuck to them.

The usable parts are the stems and tuberous roots. The stems are salmon-pink in colour when they are below ground. They are generally smooth and fleshy, up to 50 cm long and 5 cm wide. The swelling process of the stems and the accumulation of nutritive substances are typical of Nyctaginaceae; they are the result of cambium activity creating irregular peripheral tissues around the external part of the stem. Towards the centre, several elliptical rows of isolated xylem vessels may be seen. The basic tissue is parenchymatous with an abundance of water, many starch grains and some cream-coloured fibre.

Ecology and phytogeography

The only information available on *M. expansa*'s environmental requirements relates to Cajamarca in Peru, where the most evident ecological area for the crop would appear to be the semihumid quechua (2 300 to 3 500 m), with a mean annual temperature of 13°C and with maxima of 25°C and minima of 5°C; deep soils with abundant organic matter and an annual precipitation of 680 mm.

Explorations and collections carried out to locate cultivated forms and wild relatives of the mauka reflect its geographical distribution.

In Bolivia, the mesothermal valleys of La Paz up to the point where they join the yungas: the province of Camacho, the cantons of Italaque and Mocomoco, the Yokarguaya communities towards Muñecas, Saavedra and Larecaja; the yungas of the north and south; Inquisivi towards Cochabamba; and, in the case of *M. postrata* in La Paz, Achumani, at 3 500 m (Cota Cota National Herbarium, La Paz).

In Ecuador, Cayambe and Mojanda in Pichincha, with two morphotypes. In Ibambura, San Pablo. In Cuvinche-La Esperanza, a native species with a yellow root and white flowers can be cooked quickly. Another introduced species with a white root and magenta flowers is collected from June to November. At 3 100 m in Cañar, Ingapirca, *M. postrata* and Moradilla or Pega Pega occur, with white and purple flowers.

In Colombia, Beteitivá, the basin of the Otengá River towards the wild barren plain of Las Puentes in Boyacá, there are wild forms at 3 100 m.

In Peru, Cajamarca is the centre of the widest diversity thus far described, with specimens collected from five provinces and 15 districts – the provinces of Celendín, Chota and Cajamarca being the most prominent; three provinces and 28 additional districts are indicated. The mauka also exists in other departments: La Libertad, Ancash, Amazonas and possibly to the south of Ayacucho as far as Cuzco and Puno. Wild specimens have been found in Huarochirí in Lima.

Genetic diversity

No definite cultivars exist, but the plants are differentiated by root colour, with White, Yellow and Light Orange being distinguishable.

At present, three collections of germplasm are available in the case of the cultivated species in Peru and Ecuador, where characterization has taken place and material is stored in live banks. In Cajamarca, there are 32 accessions at the Baños del Inca experimental station (INIAA) and three at the Faculty of Agronomy of the Technical University of Cajamarca. In Ecuador, there are three accessions at the Santa Catalina experimental station (INIAP).

In the specimens evaluated in Cajamarca, root and foliage development is greater because of the more abundant precipitation compared with the Andean south. The astringency of the newly harvested roots should be pointed out in the Bolivian specimens compared with those from Ecuador, which are sweeter. A more detailed characterization is needed within the various collections. It may be added that, in rural areas, women have valuable information on the characteristics of cultivars.

Cultivation practices

Little is known about the cultivation of *M. expansa*, which is reputed to be hardy and is grown under peasant farming systems. The details given below come to a great extent from information obtained on germplasm collection trips.

Vegetative propagation is the technique normally used: basal shoots, pieces of stem or suckers. It is also reproduced by seed. Plants which have developed from basal shoots are harvested at the end of one year. This period can be longer if suckers are used. They are planted in furrows in holes measuring 1 × 1 m. Because of the frailness of the plants, earthing up must be done carefully.

The production cycle generally lasts about seven to nine months. In Ecuador, it is planted from July to August, intercropped with maize, which allows a better soil structure for root development by preventing the proliferation of slugs and attacks by a certain dipteron which bores into the plant's underground parts.

Phenology of the crop.

- From planting to emergence: four to seven days.
- From emergence to the first pair of leaves: six to nine days.
- From the first pair of leaves to the start of tuberization: 25 to 30 days.
- From the start of tuberization to flowering: 100 to 110 days.
- From flowering to harvesting: 90 to 100 days.
- Production cycle: 225 to 256 days.
- Appearance of the first roots: 22 days.
- Cuttings that take root: 96 percent.
- Number of roots per cutting: 23.
- Number of roots per plant (on peasant plot): two to five.
- Length of roots at 45 days: 3 to 12 cm.

Yield.

- Yields per plant (two seasons): 0.5 to 2 kg.
- Weight of plant (on peasant plot): 3 to 5 kg.
- Yield per hectare: 12 and 52 tonnes.
- Yield of green fodder per plant at 6.5 months: 7 kg.

There are no official statistics on production, area under cultivation or yields.

Prospects for improvement

The mauka is a crop which has been reduced to family vegetable gardens and its conservation is mainly due to the interest of the peasants who value its production and appreciate its taste.

Its reproduction is cheap because of the ease of propagation from cuttings. However, it competes with other roots, since soil availability is limited in the agro-ecological area in which it is cultivated.

With an adequate selection of varieties and the development of a more appropriate cultivation technology, its production and marketing could be increased in some areas.

There is an interest among the peasant communities which are providing genetic material so that *M. expansa* can continue to be produced and consumed.

The National University of Cajamarca has set up a tissue culture laboratory and is able to experiment with germplasm stored *in vitro*.

Lines of research

Expansion of *M. expansa*, both within and outside its habitat, must be founded on basic applied research. There is still much to be learned about its botanical, biochemical, physiological, phenological and agronomic aspects that will allow more information to be obtained on cultivation practices, environmental photoperiod and thermoperiod requirements, humidity, soils, pests and diseases.

- As a preliminary measure, the existing genetic material must be completed and characterized and the most acceptable ecotypes must be selected with producers.
- The genetic base needs to be broadened for characterizations and evaluations to be carried out and methods of storing collections need to be improved.
- The existence of variability in the astringent nature of the root means that varieties might be bred with a lower oxalate content.
- Biochemical research on this root could also enable the selection of materials with a better nutritional balance as regards protein and trace elements.

LEAFCUP
(*Polymnia sonchifolia*)

Botanical name: *Polymnia sonchifolia* Poeppig & Endlicher
Family: Compositae
Common names. English: leafcup, yacón; *Spanish:* yacón, yacuma, jícama (Ecuador, Bolivia), arboloco (Colombia), jícama (Peru)

Originating in the Andes, *Polymnia sonchifolia* is grown from Venezuela to northeastern Argentina, on the slopes of the range with subtropical and tropical climates at around 2 000 m. The wild forms were found by Bukasov on the Cundinamarca plateau in Colombia. It is a typically peasant crop. Its production increased during the widespread drought which laid waste the Andean region in 1982-1983, when potato production (which was seriously affected) was replaced by that of the leafcup with good results.

Its marginalization is connected with the absence of an intensive production technique which can be traced to the fact that this species is not customarily eaten in urban areas.

Uses and nutritional value

The pleasant-tasting sweet roots are eaten raw after they have been exposed to the sun for several days until the peel shrivels. Because it is easy to digest, it is used in invalids' diets in the usual areas of cultivation. Cattle and pigs also eat the roots together with the foliage.

In Ecuador, ten clones were evaluated during the one-year productive cycle, with the following yields: raw root, 41 tonnes per hectare and peeled root, 34 tonnes per hectare. The dry matter content of the roots is 15 percent.

The average sugar content increases as it becomes concentrated in the roots which are exposed to the sun for two weeks: fructose, 2 to 22 g per 100 g in fresh roots; alpha-glucose, from 2 to 7 g; beta-glucose, from 2 to 6 g, and sucrose, from 2 to 4 g. The sugars are similar to inulin. As in the case of sugar cane, the sugars can be concentrated to obtain sugar or molasses. There is also agro-industrial potential for converting these sugars into alcohol.

From the foregoing, the great agronomic potential of *P. sonchifolia* may be appreciated. It is also used as a soil protector because of its ability to maintain itself as a perennial species, especially in dry agro-ecological areas.

Botanical description

P. sonchifolia is a perennial plant which forms a densely ramified root system from which cylindrical stems grow to about 1.5 m in height. The leaves vary in shape, being pinnatifid at the base of the stems and triangular on the apical part. The flowers appear on terminal branches and have five pointed, green, triangular bracts. The outer flowers have long ligules which are 10 to 15 mm long, yellow or orange in colour and denticulate at the apex, while the central ones are tubular and about 8 mm in length.

The roots are irregular or fusiform and develop ramified masses at the base of the plant. They are purple on the outside, while the inner part is fleshy and orange-coloured. It is propagated from shoots taken from the collar of the plant.

Ecology and phytogeography

Little information exists regarding the environmental requirements of *P. sonchifolia*. However, according to field observations, they are as follows:

Photoperiod. The plant develops under both short-day and long-day conditions.

Humidity. Because of its growth habits, it requires humidity in the first stages, but afterwards can tolerate periods of drought.

Altitude. *P. sonchifolia* is grown at sea level in Peru, New Zealand and the United States, although there is no information on the production of usable roots, except in New Zealand where it is grown commercially. Its upper limit appears to be 2 000 m.

Temperature. It tolerates high temperatures and minimum temperatures of 4 to 5°C.

Soil. It shows wide adaptation for foliage production. However, to produce edible roots it requires deep, rich and well-drained soils.

Geographical distribution

In Colombia, it is grown on the tableland of Cundinamarca, Boyacá and Nariño, from 2 600 to 3 000 m on the high, bleak plateaus.

In Ecuador, it is grown from 2 400 to 3 000 m sporadically between maize fields and in vegetable gardens in the inter-Andean corridor in the following order of importance: in Loja, Azuay, Cañar, the lakeside area of San Pablo in Imbabura and in Bolívar province.

In Peru, cultivated varieties are found from 1 300 to 3 500 m, with the greatest concentration in the north and southeastern sierra, between 2 000 and 3 000 m.

In Bolivia, it is grown around 2 500 m, at a maximum altitude of 3 600 m at the head of the valley to the north of La Paz (the provinces of Larecaja, Camacho, Muñecas, Bautista Saavedra); in Cochabamba de Pocona towards the south, Chuquisaca and the mesothermal valleys of Santa Cruz.

In Argentina, it grows to the northeast of Jujuy and Salta.

Genetic diversity

The IICA began leafcup collections in 1963. Since then, 88 collections have been obtained in Peru, especially from Cajamarca.

In Ecuador, 24 collections have been gathered and a wild form has been found (the best time for collecting is from June to August). A preliminary evaluation has been made of the sugar content in ten clones.

The best-known cultivars in each country – White, Purple and Yellow – coincide insofar as the colour of the edible part of the roots is concerned: Yellow is the most sought after.

Cultivation practices

Traditional cultivation begins with the preparation of ploughed maize or potato fields, where the shoots are planted in furrows. Sowing can be done throughout the year provided there is moisture in the soil. Earthing up is done just once. The plants reach maturity at approximately seven months in low areas and in one year in the highest areas such as the heads of valleys.

The roots break easily and must be harvested with care and then separated from the central stem which is then used for livestock feed. They are stored in dark, dry places where they are kept for months and become sweeter because of starch conversion. The sun's action accelerates this process. In intensive crops, yields of up to 40 tonnes per hectare can be obtained.

Prospects for improvement

The fresh root of *P. sonchifolia* has a high water content, hence its food value is low.

In the Andean region, there is a potential demand. In other subtropical and tropical regions of the world it could be developed as an industrial crop for inulin production. The leafcup could also acquire importance as a perennial fodder and cover crop in arid conditions. In this connection, it would appear as a component of multiple complementary crops.

Lines of research

The leafcup needs to be "rediscovered" through the following measures if its cultivation is to be extended:

- completing explorations and systematic collections of cultivated and wild forms;
- coordinating the characterization, agronomic evaluation of the material and determination of sugar content and quality carried out by the current gene banks;
- determining the optimum conditions for storing roots and leaves;
- evaluating the use and quality of green and hay fodder;
- studying diseases and obtaining tolerant material or determining control methods;
- testing meristem culture;
- developing technologies for mechanized cultivation.

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Andean fruits

PEPINO
(*Solanum muricatum*)

Botanical name: *Solanum muricatum* Aiton, *S. variegatum* R. & P., *S. pedunculatum* Roem & Schult, *S. guatemalense* Hort.

Family: Solanaceae

Common names. *English:* pepino, sweet cucumber, pear melon; *Quechua:* cahum, xachum; *Aymara:* kachuma; *Spanish:* pepino, pepino dulce (Colombia, Ecuador, Peru, Bolivia), mataserrano (central and southern Peru), peramelon (Canaries)

The pepino, *Solanum muricatum*, originates from the Andean region and has been domesticated since pre-Hispanic times. At present, it is known only as a cultivated species. Its names in native languages and representations on various ceramic objects of the Chimú and Paracas cultures are proof that it was a widespread and important crop in those days. This was not so during the settlement or the Republic. During the settlement, the Viceroy Melchor de Navarra, Count of la Palata, prohibited consumption of this fruit and gave it the pejorative name of "mataserrano" (highlander killer). The Spanish word pepino might have been intended to facilitate the introduction of *Cucumis sativus* L. (Cucurbitaceae), a species also known by this name, as the names have been confused since then. On the northern coast of Peru (in the Virú and Moche valleys), farmers believe that if pepinos are eaten after drinking liquor, death may result. Names and beliefs have contributed towards *S. muricatum* being grown in small areas and its introduction is still at the incipient stage. The situation is not the same in the countries where it has been introduced, however. Commercial crops produced with advanced technology are known in Chile, New Zealand and the United States (California) as a result of this fruit's acceptance on North American, European and Japanese markets.

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Uses and applications

The fruit of *S. muricatum* is eaten ripe as a refreshing, quenching fruit after physical effort. Herdsmen of Moche and Virú take pepinos in knapsacks for eating during long treks through the desert.

Its yellowish white colour, with speckles and longitudinal lines, and its purple colour in the ripe state make the fruit attractive. Its smell and taste are pleasant because of their typical mild aroma and slightly sweet flavour. Its nutritional value is low but it is recognized for its diuretic properties, probably because of its high water content (90 percent) and good iodine content, for which it is recommended for treating goitre. It also contains 7 percent of carbohydrates and 29 mg per 100 g of vitamin C.

Botanical description

S. muricatum is a herbaceous plant of a very branching habit and with a woody base. It has abundant foliage, with simple or pinnate leaves (one to three pairs of folioles) and elliptical-lanceolate, strigose or glabrous laminae and folioles. The inflorescence is subterminal with few flowers. The flowers are pentamerous, the calyx persists on the fruit and the actinomorphous corolla is 2 cm in diameter and bluish in colour with whitish margins.

The stamens are shorter than the corolla, the anthers are yellow, connivent and dehiscent through apical pores. The style emerges slightly in between the anthers. The fruit is ovoid, conical to subspherical, and it may be with or without seeds.

Phenology. Plants propagated vegetatively grow quickly and begin to flower four or five months after sowing.

The biological cycle with this kind of propagation is as follows:

- *Cuttings taking root:* this is very quick (ten to 15 days) in damp soil.
- *Vegetative growth:* this is manifested by branches and leaves emerging in abundance and lasts three to 3.5 months.
- *Flowering and fruiting:* this is abundant because of the number of branches and lasts 1.5 to 2.5 months.
- *Postharvest stage:* this is a period of rest for the plant during which no branches or leaves are put out; it is the right time for taking cuttings for propagation and at the same time for pruning the plant.
- *Resprouting:* with greater humidity, the plant begins a new phenological cycle.

Plants propagated by seed take longer to develop. In spite of the fact that the plant is perennial, growers only avail themselves of two fruiting seasons, since fruit yield and quality subsequently diminish.

The seeds' viability after removal from the fruit is not known but, in the vegetable gardens where they are grown, seedlings frequently appear. In the laboratory, seedlings have been obtained even after 15 to 20 days of seed drying.

Ecology and phytogeography

S. muricatum is a tropical species of temperate, mountain and coastal climates. In the Andean region, cultivation takes place in the inter-Andean valleys and on the western slopes, from 900 to approximately 2 800 m. These boundaries are set within 24°C at the lower limit and 18°C at the upper limit, with an annual precipitation of between 500 and 800 mm. The climatic characteristics described correspond to the high part of the subtropical dry forest and the low dry mountain forest or to the high yungas and quechua of Peru. Coastal cultivation takes place south of lat. 7°S. during the autumn and winter when the temperature fluctuates between 21 and 17°C and atmospheric humidity increases as a result of mists and drizzle.

The original cultivation of *S. muricatum* extended along the Andes, from southern Colombia to Bolivia and the Peruvian coast. During the settlement, it was introduced into Mexico and Central America, where it was known as *S. guatemalense*.

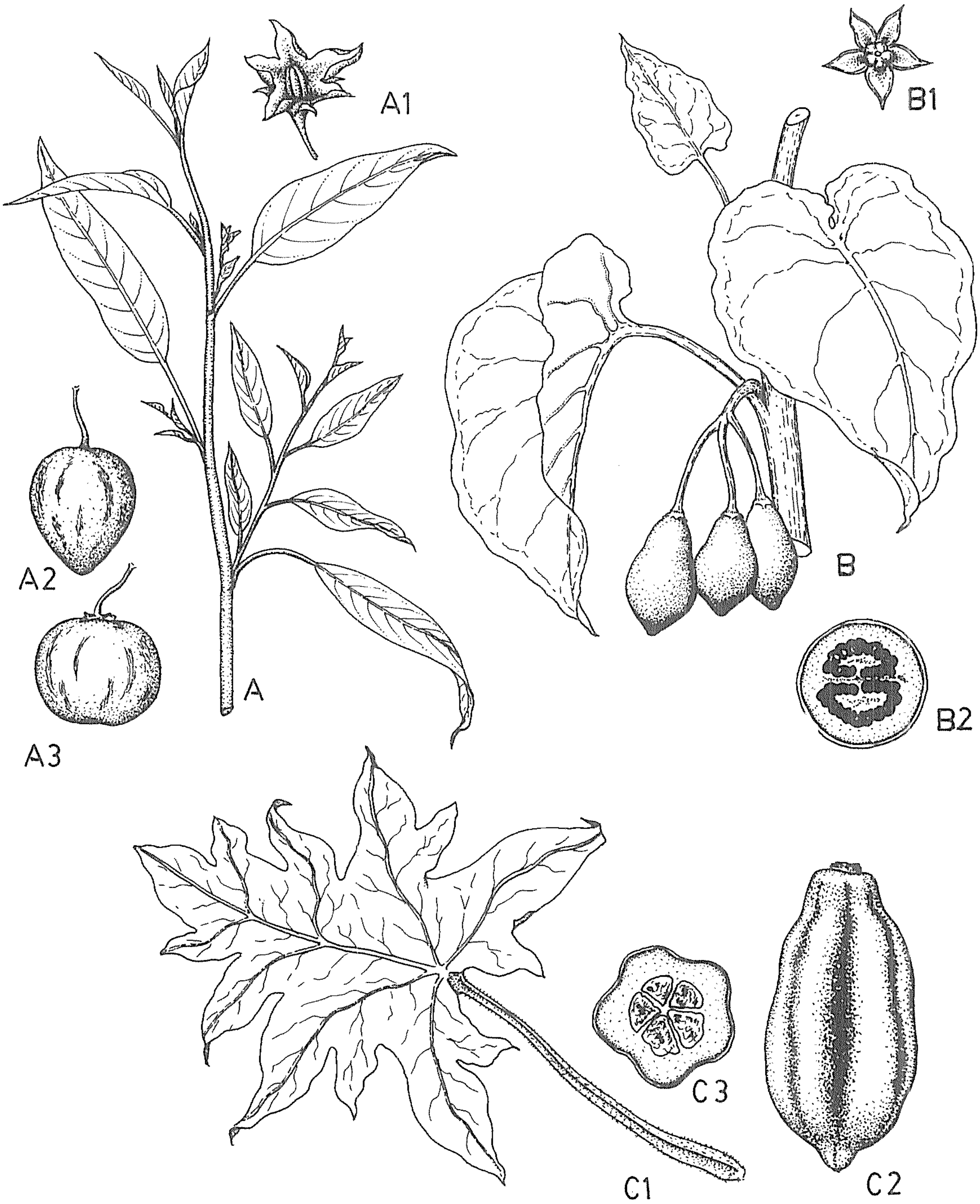
Genetic diversity

The species displays wide intraspecific variability, which has given rise to the aforementioned synonymy. Morphological variation is evident in the division of the leaf lamina (compound and simple), the pubescence of the stems and leaves (glabrous-strigose) and the shape, colour and consistency of the fruit. A physiological variation has been detected in the formation of the fruit and seeds, since there are certain biotypes that produce fruit after pollination and contain fertile seeds and others which, owing to the sterile pollen, form parthenocarpic fruit without seeds.

Correlations have not been established between the characteristics described, and they warrant specific research. Varieties and forms have been described. As regards varieties, Protogenum is characterized by compound leaves and

FIGURE 21

Andean fruits: A) pepino (*Solanum muricatum*); A1) flower; A2), A3) fruits; B) tree tomato, tamarillo (*Cyphomandra betacea*); B1) flower; B2) cross-section of the fruit; C) mountain papaw (*Carica pubescens*); C1) leaf; C2) fruit; C3) cross-section of the fruit



Typica by simple leaves. Within the latter, the form *glaberrimum*, which has glabrous leaves, is distinctive.

Related wild species. This is a still undefined aspect. Research based on interspecific crossings reports *S. muricatum* with *S. caripense* H. & B. ex Dun., *S. tabanoense* Correll and *S. trachycarpum* Bitt & Sodiro. Of these, the first is regarded as having greater potential for such genetic affinity in that fertile hybrids have been obtained. There is less evidence in the case of the other species but, in that of *S. tabanoense*, the origin of *S. muricatum* could be southern Colombia and Ecuador, since this is the natural area of distribution of the species to which it is related.

Known cultivars and centres of diversity. On the sierra of Cajamarca in Peru, the typical form of *P. muricatum* is found with regular frequency, with subspherical fruit, a pressed apex, and in a yellowish green colour with some purple speckles. On the Peruvian coast, the form *glaberrimum* has been found in pure and commercial crops, of which two cultivars can be distinguished:

Morado listado: This has dark green leaves, suberect branches and ovoid-conical fruit of variable size. It has a yellowish, very sweet mesocarp. This is the fruit most valued on the market.

Oreja de burro: This has light-green leaves and long branches; it is semi-prostrate, has elongated conical, large or medium fruit with little pigmentation (white pepino) and its mesocarp is sandy white and less sweet.

The variety Protogenum has been described in the case of Colombia and Ecuador, where cultivars are unknown. On the northern coast of Peru, a purple pepino is known, which is subspherical in shape and very sweet. The growers consulted say it has disappeared.

Living material needs to be collected throughout the distribution area of *S. muricatum* in order to set up a gene bank.

Cultivation practices

Propagation is generally by cuttings. To prepare the cuttings, healthy, mature branches are selected and cut at a length of 30 to 35 cm. They are then left in the shade for two to three days to induce a slight dehydration and encourage rapid rooting. The soil, with sufficient humidity, is prepared by ploughing in furrows. After four to five days, the furrow is "cleared", which consists of breaking up the soil and deepening the furrows to achieve a good infiltration of water, without waterlogging the ridge. The cuttings are planted 50 cm apart under damp conditions, on the lower third of the side of the ridge. The distance between furrows is 80 cm.

Tilllage consists of irrigation, hoeing and earthing up. Irrigation is frequent during the first few days after sowing and is then carried out at intervals as required. When the fruit is ripening, irrigation is suspended. Earthing up is carried out 30 to 35 days after sowing and is used to bury the fertilizer.

In Peru, *S. muricatum* is not grown very much commercially and the yield per unit of area is not known, nor is the extent of its cultivation.

Prospects for improvement

The limitations in the countries of origin are determined by:

- the "social marginalization" of the fruit, which is the reason for its low consumption;
- the underuse of genetic variability;
- a lack of commercial techniques;
- inadequate transportation of the fruit.

However, these limitations are not factors which definitively prevent extensive cultivation of *S. muricatum*. This is one of the native species with the greatest potential for overcoming its current marginalization, as the availability of fruit can easily be diversified and the potential for consumption and export widened.

Lines of research

Sustained promotion of *S. muricatum* cultivation must be based on a multidisciplinary research programme that includes:

- botanical explorations within its primary distribution area that make it possible to recognize the extent of intraspecific variability and to define the centres of genetic diversity;
- anatomical and morphological, floral biology and cytogenetic research to interpret ecophysiological behaviour and genetic variability;
- research into phenology and agronomic cultivation techniques in various ecological areas in order to establish nutritional and health requirements and yield potential.

The lines of research must be orientated towards characterizing cultivars and setting up a gene bank.

The alternate use of vegetative and sexual propagation must be better exploited. Vegetative propagation is used to stabilize varietal forms and shorten the biological cycle and sexual propagation is used to promote genetic diversity.

TREE TOMATO
(*Cyphomandra betacea*)

Botanical names: *Cyphomandra betacea* (Cav.) Send., *C. crassifolia* (Ortega) Kuntze, *Solanum crassifolium* Ortega, *S. betacea* Cav.

Family: Solanaceae

Common names. English: tree tomato, tamarillo; ***Spanish:*** tomate de árbol, berenjena, sachatomate, yuncatomate (Peru), limatomate, tomate de monte, tomate de La Paz (Bolivia, Argentina)

This is a native species of the Andes whose domestication and cultivation took place before the discovery of America. In spite of its age, no names are known in native languages.

Uses and nutritional value

Cyphomandra betacea is cultivated for its fruit which is a food resource and a potential raw material for the preserves industry. The peasants attribute to the fruit medicinal properties for alleviating respiratory diseases and combating anaemia. The tree tomato contains adequate levels of vitamins A, B_6, C and E and iron.

The fruit is eaten raw or cooked. In all cases, the skin is removed as it has a bitter flavour. When ripe, the fruit is eaten raw as a fruit. More frequently it is eaten as a dessert of fruit in syrup. The whole pedunculated fruit is cooked for a short time in water so that the skin can be removed. Honey is then prepared with cinnamon and cloves, the peeled fruit is added and it is left to boil until it reaches a suitable consistency.

In the pre-ripe state, when the fruit takes on an orange colour, it is used in Peru to prepare a sauce together with *Capsicum pubescens* R. & P., a variety of large green pepper. To prepare this, the fruit is lightly grilled, which facilitates removal of the skin (epicarp). It is then ground with a large green pepper and salt. This spicy sauce is eaten as an appetizer. In those areas of the sierra where tomato (*Lycopersicon* sp.) is not grown, tree tomato is used to prepare stews, thus replacing tomatoes.

Botanical description

Cyphomandra betacea is a small tree, growing 2 to 3 m in height, with a single trunk that is monopodial and branched at a height of 1 to 1.5 m into two or three branches. The same pattern of ramification is repeated on the branches. The leaves are cordiform, 17 to 30 cm long, 12 to 19 cm wide, subcarnose and lightly pubescent on the underside. There is a caulinar inflorescence opposite the leaf. The flowers are 1.4 cm long, the calyx persists on the fruit, the corolla is pinkish white and rotate-campanulate with reflexed apices, connivent stamens that are shorter than the corolla, yellow anthers and is dehiscent through two apical pores. The style emerges between the anthers. The fruit is 5 to 7 cm long, ovoid, glabrous, greenish yellow to orange in colur, with longitudinal markings, and the mesocarp is orange.

Phenology. Apparently no research has been done on the growth phases of this plant. Consequently, the following phenological description is an approximation and the result of field observations and information provided by peasants. Propagation is most frequently by seed but can also be based on cuttings.

The plant's life is approximately three to four years and flowering begins eight to ten months after sowing in the permanent location. The flowering period begins at the same time as branching of the main stem. The first inflorescence is produced around the point of branching of the main stem and the following ones at the end of the branches, around their respective branching. Flowering is continuous and the number of inflorescences is directly proportionate to the plant's branching.

The plant is evergreen and constantly puts out leaves. However, the lower leaves later fall, leaving the main stem and lower part of the branches leafless.

Ecology and phytogeography

C. betacea grows best in regions with temperatures between 18 and 22°C and annual precipitations of 600 to 800 mm. These climatic characteristics occur in the Andes at average altitudes (1 800 to 2 800 m). Observations in family gardens show that the plants grow better in association with trees (e.g. *Erythrina edulis*, *Juglans neotropica*), where a more humid microclimate has formed, with less soil dehydration and where the light is diffused. Tree tomato plants do not tolerate low temperatures (frost). High temperatures also affect flowering and fruiting, as do prolonged droughts.

C. betacea is cultivated sporadically from Mexico and the Antilles to Argentina. No wild populations are known and its domestication is presumed to be recent. Cultivation extends to subtropical areas such as New Zealand, where it is very advanced, southern Europe and tropical areas of other continents, India and Southeast Asia.

Genetic diversity

C. betacea is known only in the cultivated state. Populations display variability in the pigmentation of the young foliage and in the colour, shape and thickness of the fruit's mesocarp. Some of them have groups of silicose cells on the mesocarp, which lowers the quality of the fruit. According to growers, the yellowish green leaf colour is related to the production of yellowish fruit and the purple-green foliage with the production of orangey-red fruit. The shape of the fruit varies from subspherical to ovoid with a slightly pointed apex. Research on this aspect is necessary to elucidate the extent of variability and the phytogenetic relationship with wild species.

Related species. There are around 50 species of *Cyphomandra* which are found from southern Mexico to Argentina. *C. bolivariensis* and *C. hartwegii* are considered to be species related to the tree tomato. *C. hartwegii* produces edible fruit, is grown sporadically and has been used as grafting stock. Another species with edible fruit, *C. cajanumensis* or casana, originating from Ecuador, is cultivated in New Zealand.

Cultivation practices

Commercial cultivation of *C. betacea* is incipient, in spite of the fact that it is frequently grown in the gardens of rural and urban houses. In these gardens, very few plants (two to four) are grown for family consumption and only occasionally it is sold on local markets.

Cultivation techniques are based on propagation from seed and there are therefore two stages in cultivation:

Seed bed. Seeds from ripe fruit are left to dry outside for ten to 15 days and are then put into a seed bed. They are left there for 30 days to germinate and reach 15 to 20 cm in height (with three or four leaves), at which point they are planted out in their final location.

Sowing. Since the plants are grown in gardens where there is no regular planting, no information is available on the depth of sowing, the distance between plants, tillage practices or crop protection.

Cultivation based on vegetative propagation is very rare. In Colombia, it is reportedly grown from cuttings which must be 20 to 30 cm in length and which take root 30 days after planting, at which stage they are thus suitable for planting out. In Cajamarca in Peru, one case of propagation from cuttings is known to have been carried out experimentally by a grower.

Prospects for improvement

Cultivation of *C. betacea* shows promise and should be the subject of research and experimentation in commercial crops which allow relevant technologies to be developed.

The limitations of *C. betacea* are determined by the traditional state of cultivation rather than by the plant's characteristics. The present situation is characterized by:

- a lack of identification of cultivars;
- an absence of commercial cultivation techniques and plant management (plant regeneration and pruning techniques);
- cultivation limited to family gardens;
- the presence of mycotic diseases (*Oidium* sp.) and insect pests which attack the leaves.

It has been found that the species is not very stable in the characteristics obtained through selection, such as colour, size, sweetness of the fruit and yields. However, it should be recognized that those characteristics have been detected in cultivars developed outside the natural distribution area (New Zealand) where ecological factors may have had an influence.

The tree tomato's prospects are determined by the quality and diversity of use of its fruit. The most important and potentially exploitable is industrial processing of the fruit for preserves. This agro-industry would promote cultivation over larger areas and extend the market, while cultivars would be developed with bigger yields and better-quality fruit.

Lines of research

Intensive cultivation of *C. betacea* for industrial purposes involves carrying out various research studies aimed at achieving greater production. With this in mind, the following activities are recommended:

- Experimenting with vegetative propagation using hormones which accelerate rooting and activate buds; the results could bring forward the flowering period.
- Looking for techniques for pruning and activating dormant buds. Removal of apical dominance at an early age causes branching at lower altitude. After their second year, the plants have many dormant buds on the lower part of the branches and on the main stem which, when activated, would form new branches and increase production.
- Recognizing the genetic variability of the

species within its natural geographical distribution as well as that of related species in order to select cultivars and try to obtain hybrids.

- Investigating floral biology and identifying the possible role of pollinating insects.

MOUNTAIN PAPAW
(*Carica pubescens*)

Botanical names: *Carica pubescens* Linne & Koch, *Vasconcellea pubescens* A.DC., *C. candamarcensis* Hook, *C. cundinamarcensis* J. Linden
Family: Caricaceae
Common names. English: mountain papaw; *Spanish:* chilhuacán, chiglacón, chamburu (Ecuador), chamburu, huanarpu hembra, papaya de monte, papaya arequipeña, papaya de altura (Peru, Bolivia); papayuela (Colombia)

Carica L. is a genus originating from tropical and subtropical America of which 40 native species have been described from Mexico to northern Argentina. Of these, *C. papaya* L. is the most widely grown species in the tropics worldwide.

In the Andes, at altitudes where *C. papaya* cannot be grown, several species of *Carica* grow which might represent promising crops, including *C. pubescens*, which is grown in family gardens from Colombia to Bolivia. It is probable that this species was removed from the evergreen Andean forests and put into gardens to grow as a decorative plant and for its fruit, which in the ripe state is eaten raw or cooked. Not much is known about the history of this Andean fruit-tree, but its cultivation may be relatively recent, although it was grown before the introduction of *C. papaya*.

It can be assumed that the introduction of *C. papaya* into South America could have held back development of the cultivation of *C. pubescens* and other related species. The marginalization of this species can also be attributed to the indifference of the Andean populations and to the lack of incentives for undertaking botanical studies, as is currently the case with species of other families.

Uses and applications

C. pubescens is used mainly for its fruit, although other parts of the plant have a medicinal importance. The ripe fruit is used in households to make preserves and drinks. The boiled or baked green fruit can be eaten as a vegetable; when green it is also a source material for latex. Because of its papayan content, it is accepted on the international market for use in the pharmacological industry and as a meat tenderizer. In the area of greatest cultivation (Colombia, Chile and northern Ecuador), the fruit is used to treat arterial sclerosis.

In Peru, at 2 800 m in the gardens of Urubamba (Cuzco), much taller, more robust and branching plants than the Cajamarca biotypes have been observed. These characteristics mean greater production and larger fruit size, with up to 200 fruits being counted on one adult plant. The fruit is used to tenderize tough beef. To do this, the latex is removed and rubbed into the meat, which is then set aside for four to six hours. According to popular knowledge, latex is used against skin mycosis and verruca plana. It is also used as an anthelmintic, in the treatment of enteritis in children during the teething period, and against diabetes and liver diseases. Through its proteolytic effect, it acts on the cells of the skin surface and its pathogens.

Botanical description

C. pubescens is a shrub of 1 to 2 m. Its main stem has little branching and is broad-based with conspicuous leaf scars. It has the appearance of a small palm. The leaves are petiolate and the petioles are 17 to 34 cm long; the leaf blade is dentalobulate, pentagonal, 20 to 26 cm long and 34 to 40 cm wide. The leaves have a medium lobule with three to five oblong-acuminate side lobelets. The fruit is small (10 to 15 cm), five-sided and yellow. Most plants are dioecious.

Phenology. Few phenological studies have been done, particularly regarding the aspects of the plant's age at flowering and length of production. Empirical evaluations indicate that plants obtained from seed reach their flowering age at ten to 12 months and that the biological cycle ends at five years. Growth is slow and leaf emission is continuous, but the lower leaves fall off. Very few side branches are produced, except when the main shoot is cut. When the flowering stage is reached, it is continuous and simultaneous with leaf emission.

The ripe fruit is eaten by birds which pierce the mesocarp causing the seeds to fall. These have a high germination capacity, without having to go through a period of dormancy. Seeds begin to germinate at 30 days and a 60 percent germination rate has been noted.

Ecology and phytogeography

This fruit-tree grows in temperate to warm climates. In general, highland Caricaceae inhabit the low dry mountain forest area. In the Andes, these areas are situated between 2 000 and 3 000 m, depending on the latitude, and correspond to the jalca and quechua agro-ecological zones in Peru, with an annual precipitation between 500 and 1 000 mm. Mean temperatures range between 12 and 18°C (22°C in winter at midday) and the climate is subhumid.

The species is sensitive to low dawn temperatures and intense midday sun during the winter (May-September). These temperature extremes affect the foliage and normal ripening of the fruit. Although further investigation should be carried out, it is recommended that the plant be cultivated in association with other shrubs. This is deduced from its good performance in gardens that have deep soil and abundant organic matter. The plant does not tolerate prolonged drought on acount of its overprofuse leaf fall.

C. pubescens is widely distributed geographically over the Andes. It covers the western and eastern slopes and inter-Andean valleys from Colombia to Bolivia. It grows spontaneously on the Bolivian mountain ridge along with other wild species, and in Colombia as a roadside species up to the edges of the high bleak plateau.

Genetic diversity

C. pubescens is a clearly defined and delimited species as regards its morphological characteristics, although these show variations such as plant height and branching; the number of lobules and pubescence of the leaves; fruit size and colour and the quantity of latex. However, the most important differences are noted in the sexual forms of the plants. In this species, as in *C. papaya*, there are three sexual forms: pistillate plants, staminate plants and andromonoecious plants. Pistillate and staminate specimens do not respond to seasonal climatic changes while the andromonoecious specimens, which are sexually ambivalent, form female, male and perfect (hermaphrodite) flowers in different proportions, depending on the characteristics of the season.

There is no doubt that the sexual variation described, together with the ability to form hybrids with other species, offers the possibility of creating new combinations and increasing variability. The Ecuadorian species *C. pentagona* and *C. chrysopetala* have been changed to interspecific hybrids. It has been shown that *C. pentagona* resulted from hybridization between *C. pubescens* and *C. stipulata* and that *C. chrysopetala* is the result of hybridization between *C. pubescens* and *C. monoica*.

No cultivars are recognized in the geographical distribution area of *C. pubescens*, but it may be assumed that the greatest centre of diversity is in Ecuador and northern Peru. Nor is there any news of the organization of a gene bank for this species, which would prevent the loss of cultivars or biotypes created through crop selection and by ecological factors.

Cultivation practices

Current agricultural knowledge concerning *C. pubescens* in the Andes is limited. Its cultivation is traditional and it is grown in rural home gardens as a decorative plant and for fruit for household consumption. One to three plants are grown in each garden and these receive the same agricultural management as other species on the plot, so there are no specific cultivation techniques to describe for this species.

The peasants reproduce this fruit-tree from seed or occasionally from cuttings. The seeds are removed from the fruit and, after a short period of drying in the open air, they are left to germinate in baked clay vessels (flower pots) or in containers which act as germinators.

The seedlings are planted out when they are 10 to 15 cm high (two to four leaves). Pure cultivations have not been tried out and so the distance between plants is not known. However, according to the diameter of the crown, it can be estimated to be 3 × 3 m.

Yields per unit of area are not known, but garden plant countings indicate that they can produce 50 to 60 fruits in a growth period which lasts approximately four months.

Prospects for improvement

The marketing of *C. papaya* fruit at the markets of the villages and towns of the sierra limits the consumption of *C. pubescens* fruit. It could be said that the main consumers are the rural populations. Occasionally it is offered at the markets of the sierra. The best prospects for turning this species into a commercial crop, with cultivation still on a small scale, are to remove the latex in the green, semi-ripe state and to prepare processed products such as juices and preserves.

The monoecy and/or dioecy in the *Carica* species growing on high land (Andes) have given rise to some inaccuracies in species delimitation. If we add to this the affinities which exist between these species and the possibility of creating interspecific hybrids, there is an evident need to carry out basic taxonomic studies.

Lines of research

The following lines of research are suggested:

- the collection of genetic material and formation of a gene bank;
- a complete taxonomic revision of the genus;
- the completion of ethnobotanical studies;
- studies of floral biology, fruit and seed formation and the behaviour of the plant's sexual variability;
- the establishment of experimental crops to define the phenological behaviour and ways of managing the crop;
- hybridization experiments with other species and also the use of micropropagation techniques.

C. pubescens offers various options whereby the current state of its cultivation could be improved and extended but, to do this, further research is required. The crop's inclusion within the framework of commercial and extensive crops would be another factor of development for the almost depleted rural areas of the Andes.

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Amazonian and Caribbean agriculture

Crops of the Amazon and Orinoco regions: their origin, decline and future

Over the last 10 000 years, the landscapes of the Amazon and Orinoco regions have been dominated by numerous types of forest, mainly rain forest, with fields along the southern and northwestern edges. Such an immense area, which occupies almost half of South America, if the tropical forests of the Guyanas are included, may be called ecological Amazonia. As well as being ecologically continuous, there are seasonably navigable connections between the three major drainage basins: Orinoco, Amazon and Paraguay. The Amazon and Orinoco regions are joined physically and ecologically, so it is not difficult to assume that they might once also have been joined culturally.

Recent archaeological findings in northwestern Brazil suggest that the Amerindians discovered South America 40 000 to 50 000 years ago. Their migrations and cultural development can be delimited with some degree of accuracy during the last 5 000 to 10 000 years through a study of the languages, archaeology and agricultural history (crops and other useful plants).

Lathrap proposed the hypothesis that Amazonia is an important centre of origin of agriculture. His interpretation of archaeological remains identified central Amazonia as the primary centre. The phytogeography of the crops domesticated by the Amerindians suggests that the area of greatest genetic diversity is northwestern Amazonia. The domestication of medicinal and magical plants and plants for other purposes supports this hypothesis, as does the genetic diversity of cassava (*Manihot esculenta*), which is ecological Amazonia's greatest contribution to world agriculture.

Today it is becoming increasingly clear that the Amerindians' adaptation to the ecosystems of the Amazon and Orinoco regions was much more complex than can be deduced from an analysis of their farming techniques. According to Denevan, at the time of their contact with Europeans there were at least five to six million people living in the Amazon region. There were perhaps two million more in other parts of ecological Amazonia. The pressure exerted by this population was very limited in relation to the region's demographic capacity. This situation contrasts with the situation prevailing at present: a population of 20 to 30 million inhabitants living in poverty, urban settlements which require food and materials to be imported and severe environmental degradation.

Five hundred years after the first contact, it is now recognized that the original inhabitants of Amazonia had an unrivalled agro-ecological knowledge, especially compared with what exists in the region today. In many respects, Andean civilizations were also more advanced than the European adventurers who conquered them. Nowadays it is difficult to practise moderately sustainable agriculture in Amazonia, and self-sustainable agro-ecosystems are far from being developed in the humid tropics, owing to population pressure and the economic model that has

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been chosen. Whatever can be learned from the last Amerindians will help to set up more sustainable systems from an ecological, economic and social point of view.

However, one needs to be aware that cultural conservation is as important in Amazonia as biotic conservation. With the removal of the indigenous populations, a great deal of ecological and agro-ecological knowledge has been lost. The 300 000 to 700 000 people who inhabit the region nowadays are physically and culturally impoverished.

ORIGINS OF AGRICULTURE AND GENETIC DIVERSITY

The very early dates of the discovery of South America by the Amerindians shifted the timescale in which humans adapted to the rain forest.

Penetration and further colonization of this area by hunters and gatherers depended on the distribution and availability of food resources. During the rainy season there was an abundance of fruits and nuts which could feed large populations, especially in the regions along the rivers, but during the dry season plant resources were scarce. However, the newly arrived Amerindian population was small. Fish in the Amazon region was also seasonally plentiful and was an important source of protein which was easily obtained using simple techniques.

The combination of fruits, nuts, fish, reptiles and mammals constituted a very attractive concentration of natural resources. It can be assumed that colonization of the Amazon region began as soon as these resources were discovered. According to Lathrap, in an environment such as a tropical forest, with scarce resources during certain seasons of the year, it is highly likely that the Amerindians tried to concentrate these resources by sowing food plants (fruit-trees, nuts, leaves, roots) and other plants with various uses in more accessible places. If fruit and nuts were one of the main foods during the rainy season, such species were probably the first to have been tended, whereas root crops must have been domesticated later. These practices subsequently evolved into the complex system of agroforestry and forest management which is to be found today in Amazonia and neotropical regions in general.

Agroforestry is a very efficient system for improving crops, as it allows rapid genetic progress if there is sufficient variability. Over the millennia, the genetic basis necessary for modifying and completely domesticating numerous annual and perennial species in the Amazon region has been developed.

Taking as his basis the domesticated and semi-domesticated perennial fruit crops, the author proposed the establishment of a centre of genetic diversity in northwestern Amazonia, despite recognition of a wide diversity outside this centre. Table 6 shows 21 perennial, fruit-tree and industrial species from the Amazon and Orinoco regions which support the hypothesis of this centre of diversity or of a very early domestication in ecological Amazonia outside this centre.

Cassava, sweet potato (*Ipomoea batatas*), tannia (*Xanthosoma sagittifolium*) and other less important roots became the staple food of the region and were taken to other parts of the neotropics and later to the rest of the world. Although coca (*Erythroxylum coca*) is considered an Andean crop, there is also a domesticated variety, Ipadú, in the lowlands. The domesticated or semi-domesticated plants of Amazonia which were important to Amerindian cultures for ritual and medicinal uses also have a potential for exploitation in modern society.

THE DECLINE OF THE AMAZON AND ORINOCO REGIONS

The decline of the Amerindian societies of eco-

FIGURE 22

The Amazon and Caribbean region

TABLE 6 **Domesticated and semi-domesticated perennial fruit-trees and technological crops of the Amazon and Orinoco regions**

Species	Family	Probable origin
Ananas comosus	Bromeliaceae	Southwestern Amazonia
Annona muricata	Annonaceae	Northern South America
Bactris gasipaes	Palmae	Southwestern Amazonia
Bixa orellana	Bixaceae	Northern South America
Borojoa sorbilis	Rubiaceae	Western Amazonia
Carica papaya	Caricaceae	Northwestern South America
Crescentia cujete	Bignoniaceae	Western Amazonia
Eugenia stipitata	Myrtaceae	Western Amazonia
Genipa americana	Rubiaceae	Neotropics
Lonchocarpus utilis	Leguminosae	Western Amazonia
Macoubea witotorum	Apocynaceae	Central Amazonia
Passiflora edulis	Passifloraceae	Northern South America
Paullinia cupana	Sapindaceae	Central Amazonia
Poraqueiba sericea	Icacinaceae	Western Amazonia
Pourouma cecropiaefolia	Cecropiaceae	Northwestern Amazonia
Pouteria caimito	Sapotaceae	Northern South America
Quararibea cordata	Bombacaceae	Northwestern Amazonia
Rollinia mucosa	Annonaceae	Northern South America
Solanum sessiliflorum	Solanaceae	Northwestern Amazonia
Theobroma bicolor	Sterculiaceae	Neotropics
Theobroma cacao [1]	Sterculiaceae	Northwestern Amazonia

[1]Although cocoa has not been domesticated in Amazonia, it is included because of its genetic richness in this region.

logical Amazonia began before the first direct contact with the European adventurers. The extent of this decline before 1542, when Francisco de Orellana descended the Napo and Amazon Rivers, is unknown but it is believed that European diseases reached the interior of the region before the Spanish and Portuguese, coming from the Andes and especially from the Caribbean.

Although depopulation is the main indicator of the loss of cultural knowledge, a better index is the number of tribes wiped out during this process, since the disappearance of an ethnic group means that all its acquired knowledge and most of its agricultural artefacts (including the varieties of its crops) have also vanished. With a loss of between 90 and 95 percent of the original population, it is estimated that at least 80 percent of the ethnic groups have disappeared.

According to Lathrap, the Omagua nation in western Amazonia was completely destroyed 100 to 200 years after the arrival of the Europeans. The chronicler of Orellana's expedition, Carvajal, recorded that numerous types of cultivated fruit-trees were grown in the villages which obviously indicates that they were important components of the Amazonian diet. Fortunately, numerous cultivars of cassava, including those from floodable areas that are harvested in six months, and cultivars of numerous fruit species, remained in the region as disquieting reminders of what the diet had been like before contact had been made with the Amazonian peoples.

Each tribal group had its own stock of knowledge on useful and cultivated plants, originally obtained from the surrounding forest or imported as cultivated or domesticated forms from other areas. Each Amerindian nation may be considered as a source of different knowledge. What remains of the few that still exist needs to be conserved, not only for obvious ethical reasons, but also for economic reasons connected with the future of the Amazon region. However, the decline of ecological Amazonia has not yet reached its maximum point and the erosion of its genetic diversity and biodiversity has accelerated in recent years.

CURRENT EROSION OF GENETIC AND CULTURAL RESOURCES

Some governments of the Amazon countries are beginning to help the remaining Amerindians to resist the continuous process of acculturation, especially in Colombia. Although acculturation and population reduction are the main reasons for the erosion of genetic resources, the integrity of these resources is also threatened by other factors. The biggest threat is the rural depopulation of the Amazon peasants, many of whom are of Amerindian descent. The problem is especially serious in Brazil, where they are called *caboclos*. In the areas where the Amerindians were eliminated or which they abandoned, the *caboclos* are the heirs of what is left of the Amerindian heritage, including crops. When the *caboclos* emigrate, the crops disappear because of the competition from secondary vegetation. The *caboclo* culture also needs to be conserved, through support from governments, especially through development programmes, so that the people may maintain their lifestyle.

Another threat is the immigration of non-Amazonian groups. In Spanish-speaking Amazonia, it is the Andean or coastal peasants who are being settled with the support of their governments or simply because they have abandoned the increasingly poor mountains for the supposedly richer lowlands. In Brazilian Amazonia, it is the peasants expelled from the fertile lands of the south who go in search of new land on which to live. None of these groups knows the Amazon ecosystem, nor do they want to learn from the local experts, Amerindians or *caboclos*.

The big cattle ranches and other development projects (mining, hydroelectric systems) are a further threat, since they deforest large areas in order to obtain short-term income. These projects are active agents in the acculturation of the Amerindians, rural depopulation and the immigration of non-Amazonians. They are promoted by all the governments of the region, often through direct subsidies. Recent calculations, published by Fearnside, indicate that between 6 and 8 percent of Brazilian Amazonia has been deforested, with most of it being given over to stock farming as part of large-scale projects. In other instances, it is so degraded that it is not possible to sustain human populations adequately.

The conservation of genetic and cultural resources, and of biodiversity in general, will be possible only as part of a regional development programme. A sustainable, permanent and varied agriculture must be the basis of this programme, which will only be feasible if new species and technologies are developed. Many of these species already exist and others can easily be found being managed, cultivated and domesticated by indigenous communities in the Amazon region. Technologies must be developed from indigenous and *caboclo* techniques and cultures, with the necessary modifications made for dealing with the needs of the more numerous populations of today and the future, under a market economy.

CROPS AND WILD SPECIES THAT DESERVE ATTENTION

Ecological Amazonia has supplied a number of important crops for world agriculture and can still offer many more if scientific research and entrepreneurial action are directed towards this end. Cassava, which has already been mentioned, is considered to be the sixth most important crop in the world's diet. Tannia (*Xanthosoma sagittifolium*), the Brazil nut (*Bertholletia excelsa*), peppers (*Capsicum* spp.), pineapple (*Ananas comosus*), cocoa (*Theobroma cacao*) and rubber (*Hevea brasiliensis*) originate from this region. This section will deal only with certain groups of perennial species which have a potential for more widespread use.

Palms are a natural group including at least a dozen species with a high potential. The peach-palm or pejibaye (*Bactris gasipaes*) is the only palm of the neotropics which has been domesticated and has several potential uses in both advanced and subsistence farming.

The *Jessenia/Oenocarpus* complex contains several palms which were very important for subsistence in the region. *Jessenia bataua* contains oil in the mesocarp which is almost indistinguishable from olive oil (*Olea europaea*) and, moreover, is an excellent-quality protein. The genus *Astrocaryum* is very popular because of its fruit which is eaten fresh. Some species have potential as oilseed crops. *Mauritia flexuosa* and *Euterpe oleracea* are dominant species on the flood plains of the big rivers, where the majority of agricultural crops do not prosper, and they produce enormous quantities of fruit with little care and no fertilization. *E. oleracea* is the species which produces the greatest quantity of palm hearts for the world market. *Orbignya phalerata* is another dominant species, found in the southern limits of the Amazon region, which produces millions of tonnes of fruit which is rich in oil and starch and has an excellent woody endocarp for the preparation of carbon. Other palms provide fruit, fibre and building materials and have enormous potential as ornamental plants.

There are numerous nuts and species with seeds similar to nuts. The best known is the brazil nut, which is sown and widely used by the Amerindians as well as other inhabitants of the region and exported to international markets. A related species is the paradise nut, *Lecythis pisonis*, which has a better flavour but which is very difficult to gather, as the fruit does not fall from the tree when it is ripe. In the north, the souari nut, *Caryocar nuciferum*, was once important and may become important again. In Peru, a related species, *Caryocar glabrum*, is widely used and could be converted into an export crop if it were adequately researched. *Caryodendron orinocensis* is a promising species which is receiving a certain amount of attention in Colombia. *Couepia longipendula*, found in Manaus, is distinguished by its delicate flavour, earliness and growth in cultivation. The cashew, *Anacardium occidentale*, is native along the Brazilian coast to the south of ecological Amazonia. There are at least two related native species from the rain forests that merit investigation. Other species of nut should be the subject of scientific and market studies because of their ease of preparation, use and marketing.

Several fruits with mesocarps rich in oil and starch were important native resources managed and cultivated by the Amerindians. This group includes *Poraqueiba sericea*, a cultivated fruit species whose origin is unknown. It is domesticated and widely grown throughout the region and forms the basis of an agroforestry system aimed at the Iquitos market in Peru. *Caryocar villosum* is used mainly for its oily and starchy mesocarp and has an excellent-flavoured nut.

The succulent, aromatic fruit is abundant and can offer new options both for the fresh and processed fruit markets. The Smooth cayenne pineapple originated in the Orinoco region and is the predominant cultivar throughout the world, especially for processing.

Of the numerous domesticated or cultivated species studied by Cavalcante (1988), only a few may be mentioned here. The South American sapote or sapodilla, *Quararibea cordata*, has a resilient skin which enables it to be transported and stored easily. It has a sweet, succulent, delicious, orange flesh. The arazá, *Eugenia stipitata*, has a delicious aroma and exquisite flavour, but is extremely sour. However, it does have a great potential for processing in the agri-food industry. The camucamu (*Myrciaria dubia*) is the wild species which contains a greater quantity of vitamin C than any other fruit (±4 g per 100 g). The cupuaçu, (*Theobroma grandiflorum*) is a species related to cocoa whose flesh has a strong, bitter-sweet flavour and which is very suitable for juices or ice-creams.

Species rich in various types of essential oils are common in ecological Amazonia, as are others which produce oil, resins, gums and latex. Palo rosa, *Aniba roseodora*, which is now almost extinct owing to destructive exploitation, is used to obtain an essential oil which is in great demand on the perfume market. The leaves have been found to contain even more oil than the trunk, and it could be harvested in a sustainable rather than in a destructive way. *Copaifera multijuga* produces a liquid oleoresin directly in its trunk which can be used as a substitute for diesel. It also has a medicinal use and its application is being studied in the cosmetics industry. The sowa or sorva, *Couma utilis*, exudes a non-elastic gum which is used in chewing gums. Synthetic chicle is the component of most gums, but sowa gum has not yet been synthesized and is collected from wild trees. Unfortunately, its collection is also destructive, although it has been shown that, like rubber, it could be harvested in a sustainable form.

There are more than 100 timber-yielding species, although only about two dozen are widely marketed. As the reserves of Asia and Africa dry up, Amazonia is becoming the focus of excessively destructive exploitation since, to date, none of the region's governments has vigorously regulated forestry activity. Genetic resources are being eroded very quickly and this process can only be halted if forest management controls exploitation.

This chapter has dealt basically with the wild and cultivated perennial species, since the forest needs to be conserved not only because it is an important element in the planet's ecological balance, but because it contains irreplaceable natural and artificial products and systems. The only way of conserving it is to find development models that consider forest ecosystems and their related activities to be more valuable than timber or pasture land. The governments of the Amazon countries need to draw up sustainable development programmes which are fair for all inhabitants of the region.

NEW DIRECTIONS FOR NEOTROPICAL AGRICULTURAL DEVELOPMENT

Recognizing the value of forests is essentially a political question, since research has shown that the products extracted and scientific forest management prove to be of greater value in the long term than any of the alternatives currently practised in ecological Amazonia. This is especially true when a well-planned collection or scientific forest management system is compared with conventional agriculture on poor Ultisols and Oxisols. Collecting from wild populations is frequently seen as an imperfect system which needs to be improved by development. However, the shortcomings in this form of exploitation seem to derive more from the approach to planning at a government and international development agency level. These bodies consider it to be basically a subsistence strategy that is closely connected with rural poverty. In actual fact, as Altieri, Merrick and Anderson (1987) have shown, collecting can be turned into an important economic factor and, in the rural framework, it is already an activity that prevents many families from descending into absolute poverty.

It will obviously be impossible to maintain the whole forest area of Amazonia because it is being felled very rapidly and it would prove difficult to halt its destruction immediately. However, what is more important is that there are no proven alternatives to win the support of governments and inhabitants. For this reason, the scientific institutions of the Amazon region and their collaborators in other regions ought to develop a programme with three simultaneous approaches in order to identify a good number of new crops for the market. This programme should include conventional agriculture (monoculture), agroforestry and multipurpose forest management, and its subject should be perennial instead of annual crops.

Conventional agriculture does not require any comment, as all institutions of the region know it well. However, not all native species can be used for this model of agriculture since, when they are sown in greater densities than is normal in the traditional ecosystems or agro-ecosystems, they may be susceptible to pests and diseases that have evolved with them. An example is *Caryodendron orinocensis*, from northwestern Amazonia which grows at low density in the forest or in indigenous agroforestry systems. When the Araracuara Corporation organized a germplasm collection in San José de Guaviare and sowed it in a well-designed monoculture, *C. orinocensis* was immediately attacked by a leaf caterpillar which almost paralysed the plants' growth and made it impossible to characterize and evaluate them. This type of problem could occur in many indigenous species and it is the main reason for following a triple-approach programme.

"Agroforestry" is a new name for a very old practice which combines several crops in an ecologically integrated unit. Indigenous agroforestry – the traditional agricultural practice of ecological Amazonia – is one form of this type of exploitation. Throughout the world, agroforestry is practised by small farmers, since it is relatively labour-intensive. It contrasts with the conventional agriculture of the First World, which is capital-intensive. Development may also be based on labour instead of capital, especially since labour in the neotropics is relatively plentiful, whereas capital is less so.

Multipurpose forest management is a practice whereby a section of the forest is managed for the benefit of the greatest number of people. Conventional forest management, by contrast, has frequently excluded the region's original inhabitants and only benefited the big landowners and corporate entities. A multipurpose system of forest management should be aimed at enriching the forest with species that produce fruit, nuts, latex and essential oils as well as timber-yielding species. In this way, the forest can be harvested in different ways throughout the year to the benefit of the communities which inhabit them, instead of benefiting just a few people. Brazil's reservations may evolve towards this type of system, although the research necessary would have to be greater than in the other two approaches mentioned.

Agroforestry and multipurpose forest management require multidisciplinary research which must begin with ethnobiology and which must study the agricultural practices and customs of the Amerindians and *caboclos*. Geneticists, horticulturists and forestry experts must improve not only the genetic material used but also the indigenous exploitation systems which are perhaps not sufficiently market-orientated to be attractive to the majority of farmers, extensionists and government planners. These activities must be carried out in collaboration with business in such a way that priorities are established in terms of the market.

The future development of ecological Amazonia needs to be planned to benefit the region's inhabitants without degrading the natural environment. Conservation of cultural and genetic diversity and biodiversity must be the essential features of this programme. Forests need to be recognized as a valuable resource, and agricultural, agroforestry and management practices must be devised in such a way that this resource can be exploited rationally instead of being destroyed.

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Cupuaçu
(*Theobroma grandiflorum*)

Botanical name: *Theobroma grandiflorum* (Wild. ex Spring) Schumann
Family: Sterculiaceae
Common names. *English:* cupuaçu, cupuassu; *Portuguese:* cupuaçu

The cupuaçu is an arboreal fruit species considered to be a pre-Colombian crop plant which is still found wild in the eastern subregion of Brazilian Amazonia. Several authors rate it as one of the most promising fruits among the rich Amazonian flora, of which 271 fruit species have been described. An analysis of the potential of the fruit species native to Amazonia induced the author to propose four priority groups: 14 species considered to be domesticated, including the cupuaçu; 19 semi-domesticated species; 12 species that are not domesticated but whose domestication potential is recognized; and 13 palm species.

Botanical description

Theobroma grandiflorum is an arboreal species which reaches 15 to 20 m in height, but less than 8 m when cultivated. It exhibits trichomic branching, its leaves are simple, alternate and coriaceous, 25 to 35 cm long and 6 to 10 cm wide, with a bright-green, pubescent upper surface and grey underside. It has a cymose inflorescence with three to five flowers, five dark-purple subtrapezoidal petals, a calyx with five triangular sepals, five stamens with bilocular anthers, five staminodes and a pentagonal superior ovary with five locules containing numerous seed primordia. Pollination is carried out mainly by ants and aphids, with vespertine anthesis. The fruit occurs in the form of a drupe and is strong and pleasant smelling. It is smooth on the outside, ellipsoidal, 25 cm long by 12 cm wide and weighs up to 1.5 kg. The endocarp is white, soft and sour-tasting, containing 25 to 50 superposed seeds in five rows. The ripe fruit is harvested when it falls to the ground.

Ecology and phytogeography

In its wild state, the cupuaçu grows in high primary forests, on fertile, well-drained soils. It is commoner in the south of the state of Pará, on the banks of the Tapajós, Tocantins, Xingu and Guama Rivers, and is found up to the northeast of the state of Maranhão on the banks of the Turiaçu and Pindaré Rivers. It requires mean annual temperatures of between 21 and 27°C, a mean annual relative humidity of between 77 and 88 percent and rainfall of between 1 900 and 3 000 mm. It is grown in small domestic gardens and nurseries in eastern Amazonia in Brazil.

Genetic diversity

Twenty different species of *Theobroma* have been described but usually only 12 are accepted. Of these, nine are native to Amazonia, hence the centre of genetic distribution appears to be the western half of the region. The distribution limit of *Theobroma* species extends as far as the state of Maranhão in the east, to the foot of the Andes

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in Peru in the west, as far as southern Mexico in the north, as far as Bolivia in the south and, in Brazil, as far as the south of the state of Mato Grosso.

The genus *Theobroma* is typically neotropical and is distributed in the tropical rain forest in the Western Hemisphere between lat. 18°N and 15°S. The region with the most species is between Costa Rica and northeastern Colombia. Five sections and 20 species are recognized. *T. grandiflorum* belongs to the section *Glossopetalum*, made up of 11 species; *T. cacao* is the only species of the *Theobroma* section.

Four species of *Theobroma* have been described as producers of edible flesh: *T. grandiflorum*, *T. canumanense* Pires & Froes, *T. subincanum* Martius, (Cupuí in Brazil and Cacau de monte in Colombia) and *T. bicolor* Humb. & Bonpl., which is a small tree distributed from western Amazonia to southern Mexico. Chocolate is also made from the seeds of these species. The basins of the Napo, Putumayo and Caquetá Rivers in the upper Amazon appear to be the centre of genetic diversity of *T. cacao*, although *T. grandiflorum* is found in southern Pará in Brazil, and in Tocantins, Tapajós, Xingu and Guama.

In Pará, three cultivars of cupuaçu are known: Redondo, with its rounded end, which is the most common; Mamorano, which has a pointed end and produces the biggest fruits; and Mamau, possibly a parthenocarpic mutant. Artificial hybrids between *T. grandiflorum* and *T. obovatum* produce fruits with the characteristics of cupuaçu, but which are smaller and less resistant to witches' broom.

In Brazilian Amazonia, there are three collections of cupuaçu germplasm. The biggest is at INPA, near Manaus, with 27 accessions. The CPATU in Belém has a collection with 13 accessions and the Departamento Especial da Amazonia, which belongs to CEPEC which, in turn, comes under CEPLAC, set up a cocoa gene bank in Belém in 1976, with 1 749 accessions of *T. cacao* collected in Amazonia, seven species of *Theobroma* including three genotypes of *T. grandiflorum* and three of *Herrania*.

The cupuaçu is sustaining heavy genetic erosion. Its centre of diversity is in a subregion of southern Pará, where there has been intensive destruction of its habitat through deforestation as well as through the construction of the Tucuruí dam which flooded 2 300 km^2 of primary vegetation in the basin of the Tocantins River, where the species is still abundant in its wild state.

Cultivation practices

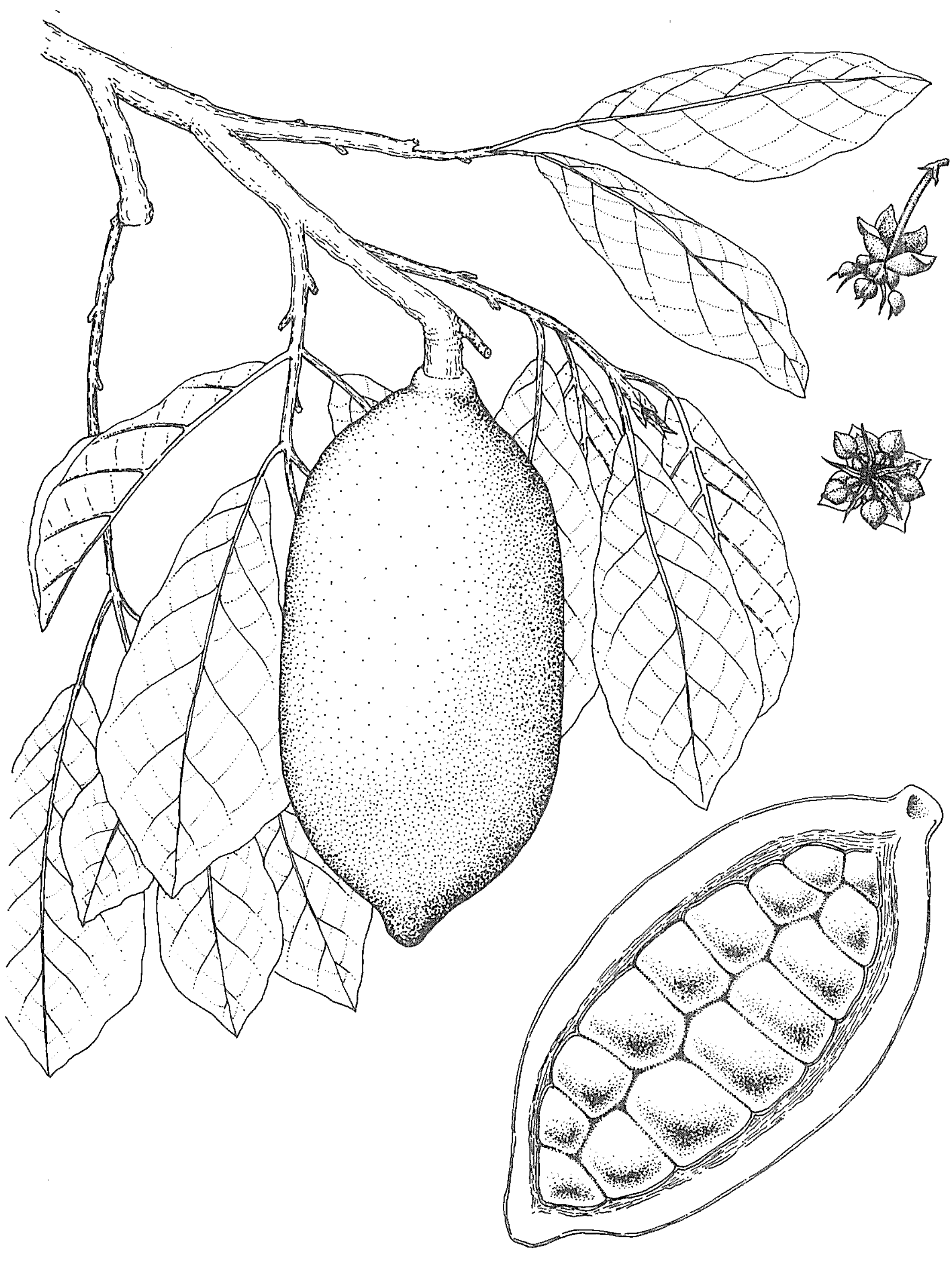
Conventional propagation techniques. The cupuaçu is generally propagated from seed, but seedless varieties such as Mamau are propagated from cuttings or grafts. As in all species of *Theobroma*, the seeds are not resistant to desiccation and are sown as soon as they have had the flesh removed and been washed.

Seed beds are prepared with fertile soil and fertilized with manure, being kept in natural shade or under plastic mesh so as to achieve 75 percent shade. From 800 to 1 000 seeds per m^2 are sown in rows set 5 cm apart, with 2 cm between seeds, and are covered with a 1 cm layer of soil. Germination takes about ten days. When the seedlings measure 10 cm, they are transplanted into 40 × 30 cm black polyethylene bags, with a rich substrate of organic matter and fertilizer. The plants are kept in a nursery in partial shade (50 percent) until they reach about 50 cm, at which point they are sown in the garden.

For propagation by cutting, young terminal branches with about five leaves are used, as in cocoa. The leaves are cut down the middle and a growth stimulant is applied to the base of the cuttings, which are placed in a propagator with saturation humidity, under a roof which provides 75 percent shade. After they have taken root they

FIGURE 23

Cupuaçu (*Theobroma grandiflorum*), flowers and cross-section of the fruit



are transplanted into black polyethylene bags and are kept in the nursery in the shade until they are ready for planting out in the garden.

Propagation by grafting requires stocks obtained from seeds of cupuaçu itself or of other *Theobroma* species, such as *T. obovatum* which produces dwarf plants.

Traditional cultivation techniques. A new cupuaçu plot requires dense shade in the first few years. If primary arboreal vegetation is still growing on the land, simply thinning the smaller trees and the creepers will suffice. In the case of deforested land, a temporary, fast-growing shade tree, such as banana, plantain, papaya, or a permanent fruit-tree such as the Leguminosa *Inga edulis*. The greatest planting distances for the seedlings are 7 × 7 m or 8 × 8 m, and 6 × 6 m for the graft trees. Transplanting holes may be 40 cm in diameter and depth and will be filled with earth that is rich in organic matter and fertilized with 10 litres of manure and 50 g of triple superphosphate. In gardens with both natural and artificial shade, the level of protection from the sun is gradually decreased after the second year until the fourth year when only some 50 percent of shade is left. Systematic control of weeds in the plot is an important task.

The cupuaçu, like cocoa, is a plant which requires nutrients and needs annual fertilization. During the growth stage, 50 g of 12-12-12 NPK + Mg are applied each year; from the fourth year, 120 g; and, during production, 500 g of the formula 15-15-13 + Mg, divided into three yearly dressings with 20 additional litres of manure. Plots with adult crops produce 7 to 10 tonnes per hectare per year.

The most serious disease of cupuaçu is witches' broom, caused by the fungus *Crinipellis perniciosa* which is endemic to Amazonia. It affects new branches, flower buds and growing fruit most seriously. The branches attacked swell and put out a great number of shoots similar to a broom, which then wither. The flower buds affected put out "small brooms". The diseased tree does not die but gradually weakens, with a conspicuous reduction in yield. To control the disease, systematic pruning of the diseased branches is recommended at least twice a year.

Current situation of the crop. Cupuaçu cultivation is concentrated in Pará where it continues to expand, although it is also grown in other states, i.e. Acre, Amapá, Amazonas and Rondônia, always in small domestic and commercial gardens. However, extractive production is still considerable. It has also been introduced into the humid tropics of Colombia, Costa Rica, Ecuador, Peru and Venezuela.

In Pará, yearly production reaches about 500 tonnes. The municipalities of Vigia, S. Antonio de Tauá, Tomé-Assu, Cametá and Capitão do Poço are the major producers.

The period of greatest abundance is the first six months, with a maximum between February and April.

Products obtained. Studies of the cupuaçu's dietetic characteristics, with the juices, nectar and preserves industry in mind, show that the fresh juice contains 10.8 percent brix, 21.91 percent amino acids, 23.12 percent vitamin C per mg and 3.0 percent reducing sugars, and that the pH is 3.3. The flesh makes up 40 percent of the fruit and seeds 18 percent. The seeds contain 48 percent sweet-smelling, white butter, which can also be used to make excellent-quality white chocolate.

The product obtained through manual depulping is generally preferred because it allows the pieces to be maintained, whereas the mechanically depulped product results in a uniform pulp that is more suited to the industrial production of juice and sorbets.

Prospects for improvement

The cupuaçu occupies a prominent place in the group of the 58 priority species. Its potential is recognized, and a growing demand is opening up possibilities of industrialization and access to the great market of central and southern Brazil as well as international markets.

Expansion of cultivation to Brazilian Amazonia does not present any serious limitations. Witches' broom disease is not a limiting factor, the climate is suitable and the availability of land makes considerable expansion of the crop possible. With extension into Colombia, Costa Rica, Ecuador, Peru, Venezuela and Mexico, it is likely to become recognized as one of the best tropical fruit-trees.

The crop is suited to small agricultural properties on account of its high profitability and secure demand.

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Peach-palm (*Bactris gasipaes*)

Botanical name: *Bactris gasipaes* Kunth
Family: Palmae = Arecaceae
Common names. *English:* peach-palm (Trinidad and Tobago), peyibay(e), pejivalle; *Spanish:* pejibaye (Costa Rica, Nicaragua), chantaduro (Colombia, Ecuador), pijuayo (Peru), pijiguao (Venezuela), tembé (Bolivia), pibá (Panama), cachipay (Colombia); *Portuguese:* pupunha (Brazil)

Bactris gasipaes was undoubtedly the most important palm of pre-Columbian America and constituted the main crop of the Amerindians of an extensive territory of the humid tropics and even some areas of the dry tropics.

Because organic material easily decomposes in the archaeological sites of the humid tropics, there are few references to findings of peach-palm material which enable its past to be reconstructed. The oldest come from seeds found in various localities on the two coasts of Costa Rica and date from 2300 to 1700 BC, when it is assumed that it was already cultivated. When contact with Europeans took place, accounts indicate that it was the main crop and sustenance of the indigenous population of the humid tropics of Costa Rica. The importance of the peach-palm also extended to numerous tribes of lower Central America and the humid tropics of South America, scattered across the basins of the Cauca, Magdalena, San Juan, Orinoco and Amazon Rivers and their tributaries as well as certain other areas. This dependence is still seen nowadays in some communities, such as the Sanema-Yanoama of Venezuela, the Shuars or Jivaros of Ecuador and the Yuracarés of Bolivia. During the years of the settlement and basically during this century, the crop has decreased in importance for various reasons.

Of these, we may mention the reduction in the indigenous population; the loss of traditions through European influence alien to these cultures and to this crop; the establishment of urban centres outside the areas of the humid tropics, where it was not traditional to grow or eat the peach-palm; the perishable nature of the fruit and the palmetto of this palm which, in the absence of processing industries, did not allow it to be traded with the new urban centres; the introduction of new short-cycle food crops; the aggressive expansion of stock farming which brought with it the extensive use of fire for land clearance and the establishment of pasture land; and, finally, soil compaction as a result of trampling by livestock. Fire, competition and soil compaction are not tolerated by this palm.

Uses and nutritional value

The use of *B. gasipaes* pre-Columbian times was complete. The fruit, its most important product, was used in two ways: cooked (boiled in water) and as a slightly fermented cool drink. In both forms, it constituted the basic food during the harvesting period in the indigenous communities which grew it. For consumption out of

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season, it was preserved mainly in ensiled form and prepared in a very similar way to today, with storage in trench silos made in the ground. One month after being covered over, it was ready for consumption or could be stored until the next harvest. This fermented material was consumed mixed with water as a cool drink. It could also be carried wrapped in leaves during journeys and merely had to be diluted in water for consumption. Another important form of preservation was drying the fruit, exposing it to heat and smoke and then placing it on mats suspended above a fire. To be eaten, it just had to be boiled in water. It was also eaten in the form of tortillas made from its dough, as with maize, or as *farinha*. The oil, which separates out when the fruit is boiled, was occasionally used for cooking other foods. Prolonged fermentation – lasting one week – enabled the alcoholic drink, *chicha*, to be made for celebrating festive occasions. Thus, the fruit of each palm constituted a basic source of energy, replacing the functions and uses of grain in other cultures. It was especially significant as a substitute for maize, which it surpasses in nutritional value.

The wood of the trunk has great strength and elasticity which enabled it to be used to make weapons – bows, arrows and spears – as well as in construction. The apical section of the trunk, together with its embryonic fronds, is soft and has a delicate flavour; from this the palmetto or heart of the palm is extracted. The sap from this part of the trunk, either unfermented or fermented in various degrees, was used to prepare nutritional and intoxicating drinks.

The young inflorescences were also eaten roasted "the herdsman's way", without opening the protective spathe. Infusions of the roots were used in medicine as a vermicide.

Today, the Indians use the same basic products obtained from the peach-palm, which now produce a greater diversity of by-products, many of which are still being developed. Thus the wood is used to manufacture building materials such as parquet, panels, luxury furniture and handicraft items, taking advantage of its beauty and great strength. The long fibres on the inside of the trunk show promise for use in fibre-cement products. Exploitation of the palmetto is a prosperous industry: having originated in Costa Rica in the 1970s, it is gradually gaining importance among the countries of the American humid tropics as a profitable crop and on account of its sound characteristics for ecological management, in accordance with new agronomic trends.

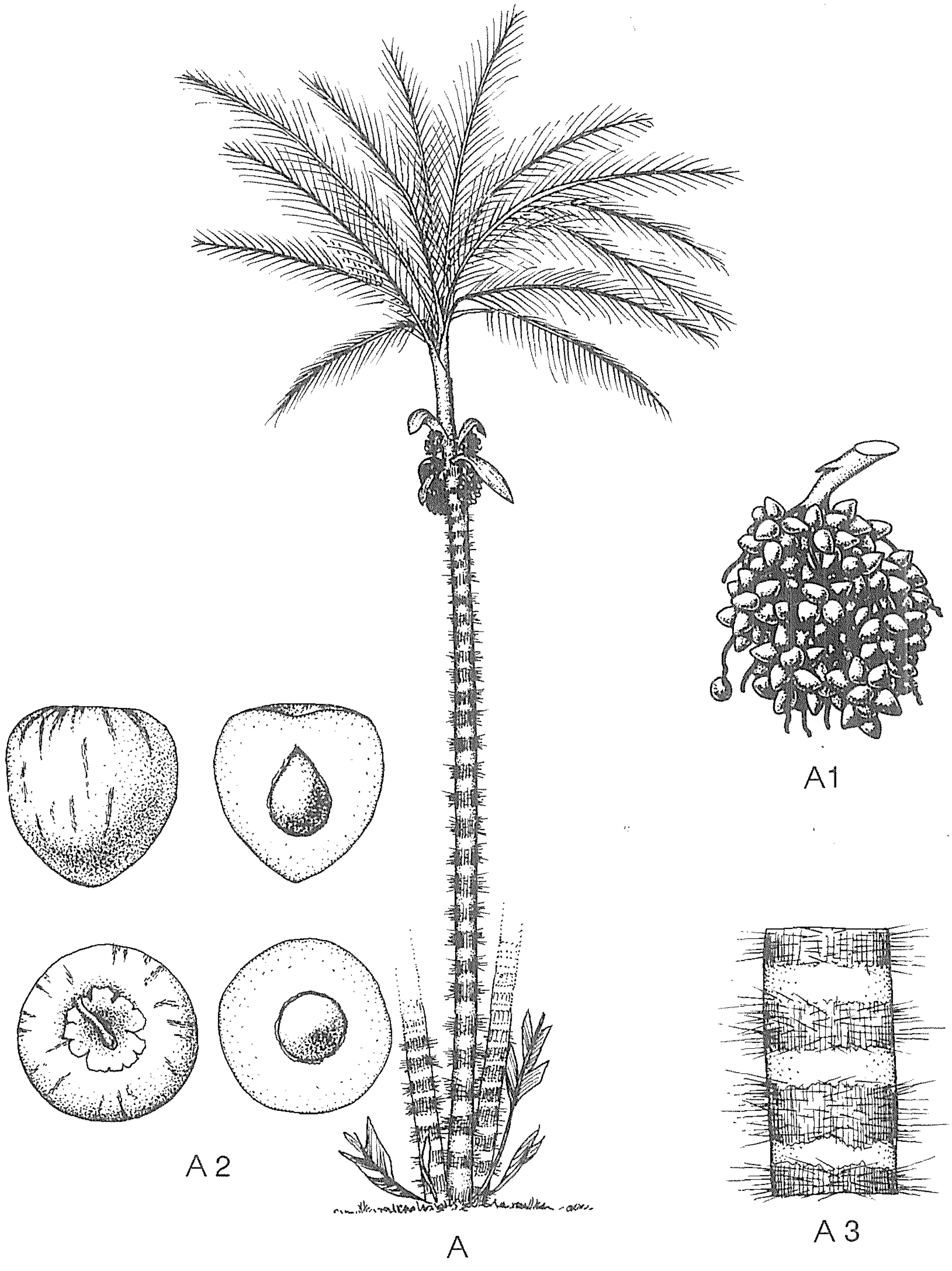
The fruit, which in the past was only important in its areas of production because it is very perishable, is now seen as having great potential through processing to form flours and other derived products such as oil, beta-carotene and starch. Tests are even being carried out to see if the trypsin inhibitor contained in the fruit of some cultivars can be used as an insecticide. Flours made from peach-palm have an important future in human nutrition, being consumed in confectionery, bread-making and other preparations. It also has a great future in animal feeding, as a substitute or supplement for grain, in the manufacture of concentrates and fermented as ensilage. Fermentation of the fruit is being investigated with a view to its exploitation in the manufacture of various organic compounds. Its possible medicinal use, as practised by the Indians, has yet to be explored.

Botanical description

B. gasipaes is a caespitose palm with an extensive but fairly superficial root system. The trunk has internodes covered with spines, alternating with nodes without spines, formed by leaf scars. These measure between 10 and 25 cm, with a lamina that is generally more than 2 m in length and with over 200 folioles. The inflorescence is

FIGURE 24

A) Peach-palm (*Bactris gasipaes*); A1) racemes with fruit in a drupe; A2) cross-sections and profile of the fruit; A3) spine-covered internodes on the stem



covered with two bracts, the outer short and thick, the inner surrounding the inflorescence until it matures; the rachis is branched with thousands of male flowers intermixed with a few hundred female flowers, which are slightly bigger than the males. The fruit occurs in a drupe of variable size – 400 to 300 g – with a slender, red or yellow exocarp; a farinaceous mesocarp which is variably orange; and a dark and hard endocarp. The size of the seeds depends on the ecotype: in the cultivated plants they weigh about 4 g, are recalcitrant and take between 45 and 90 days to germinate. Its chromosome number is 2n = 28.

Pollination. The peach-palm is a monoecious plant with male and female flowers mixed on the rachillae. It is also protogynous, since the female flowers are fertile as from the opening of the spathe and continue to be receptive for 24 hours. Anthesis of the male flowers occurs on the second day of the cycle, i.e. 24 hours after the females. In both cases this occurs at the end of the afternoon, between 5 and 6 p.m.

The pollination cycle takes place over three days and consists of three complementary methods. The first is entomophilous and is the most important. It is effected by curculionids: in Central America by *Audranthobius palmarum*; and in the Amazon basin by several species of *Phyllotrox*. Occasionally, other insects also play a part but the Amazonian *Cyclocephala* has been erroneously cited as a pollinator.

The second pollination method is by gravity. When the pollen is released during the second day, it completely covers the inflorescence and, in doing so, covers its female flowers. This method is not very effective, as there is a system of genetic self-incompatibility which interferes with fertilization and possibly produces fertile seeds only occasionally.

The third method is anemophilous, occurring between adjacent plants during the morning of the second receptive day of the female flowers. In this case, the pollen deposited on the rachillae during male anthesis is scattered by the wind on the following morning – the third day – and if there are inflorescences on nearby plants, they may be pollinated in this way on the second day.

The controlled pollination technique consists of protecting the inflorescence from the sight of curculionids, using well-fitting bags of kraft paper and applying the pollen on the day following the opening of the spathe. It is not necessary to emasculate the male flowers.

Ecology and phytogeography

The peach-palm grows wild in well-drained soils with various physical and chemical conditions, including acid and poor soils, since it is assisted by its association with mycorrhizas. It is grown in climates with precipitations between 2 000 mm and 5 000 mm and annual mean temperatures exceeding 22°C. The recommended altitude for commercial cultivation ranges from 0 to 900 m.

Its natural distribution extends from Darién in Panama to the province of Santa Cruz in Bolivia, the state of Rondônia and possibly the Mato Grosso in Brazil. Its presumed natural origin, further to the north in Central America, has not been confirmed, although it has been cultivated for several thousand years as far as northeastern Honduras. Spontaneous dispersion occurs through the seeds being carried over short distances by birds, rodents and other mammals, and over greater distances possibly by water.

Origin and genetic diversity

Cultivated peach-palm may be considered a synthetic species, the result of the independent domestication of several wild populations.

The latter, which are very extensive in their geographical distribution, were known to several primitive societies which began to grow them

TABLE 7 Species linked with the origin of the peach-palm

Species	Geographical distribution
Eastern species	
Bactris ciliata	Peru: Ucayali, Huallaga, Madre de Dios Rivers
Bactris insignis	Bolivia: Santa Cruz, Chapare, Alto Beni
Bactris sp.	Brazil: Acre, Rondônia[1]
Bactris sp.	Colombia: Alto Putumayo, Caquetá
Western species	
Bactris macana	Venezuela: Maracaibo; Colombia: Santa Marta
Bactris caribea	Venezuela: Maracaibo; Colombia: Santa Marta
Bactris chantaduro (?)	Colombia: Cauca River valley
Bactris sp.	Ecuador: Central and northern Pacific slope
Bactris sp.	Panama: Darién; Colombia: Chocó (possibly)

[1] It has not been determined whether or not the species here was *B. ciliata*.

independently. The degree of domestication reached at the time of contact with Europeans differed depending on the region. This is still reflected in characteristics such as fruit size. Thus, the cultivar developed in Bolivia from *Bactris insignis* represents an incipient stage of domestication because of its small fruit size and high fibre content, while the cultivar of the Vaupés River in Colombia reflects an advanced domestication process through its large fruit size and high starch content. The variety or species which gave rise to this cultivar has still not been determined. Between these two extremes – north and south – of the Amazon/Orinoco basin, other cultivated varieties and at least two wild species are found. One of them, *Bactris ciliata* (= *B. microcarpa*, *B. dahlgreniana*) possibly gave rise to more than one of the cultivars which are recognized today, for example Pampa Hermosa and Pastaza, which show an intermediate degree of domestication between the first two mentioned. In some cases, the presence of the wild species near the plantings had a negative effect on the improvement process as a result of spontaneous backcrossing.

The subsequent spread of the different genotypes through neighbouring regions contributed in some cases to the creation of greater local diversity. Geological and climatic history also contributed to the geographical isolation of populations, which was necessary for the process which gave rise to this complex. The gene flow between distant regions over generations has been limited in the peach-palm, since there are absolute barriers to the pollinating curculionids and to natural seed migration.

The first division between cultivars and species is based on the geographical distribution of two major groups: the eastern or Amazonian, situated to the east of the Andes; and the western, situated on the opposite slope. The former generally have a smoother trunk, with less wood, a lower spine density, fewer tufts and less soil anchorage when young. The other characteristic is fruit size, with the varieties being classified into microcarps, mesocarps and macrocarps.

The exchange of germplasm, especially in recent decades, has resulted in a considerable number of local varieties being contaminated with foreign germplasm, thereby obscuring the

TABLE 8 Cultivated varieties of peach-palm

Microcarps (weight less than 20 g)	Geographical distribution
Eastern varieties	
Tembé	Bolivia: eastern part
Pará	Brazil: state of Pará
Juruá	Brazil: Juruá River
Western varieties	
Tuira	Panama: Darién
Rama	Nicaragua: Rama, Bluefields
Chontilla	Ecuador: western part
Macana	Venezuela: Maracaibo
Mesocarps (weight 21 to 70 g)	Geographical distribution
Eastern varieties	
Inírida	Colombia: Inírida and Guaviare Rivers
Sollimões	Brazil: middle course of the Amazon
Pastaza	Ecuador: foothills of the Andes
Pampa Hermosa	Peru: Hermosa pampa
Western varieties	
Utilis	Costa Rica, Panama and perhaps the coasts of Colombia
Guatuso	Costa Rica: San Carlos
Cauca	Colombia: Cauca and Magdalena (?) valleys
Darién	Panama: Darién
Macrocarps (weight exceeding 70 g)[1]	Geographical distribution
Eastern varieties	
Vaupés	Colombia: Vaupés River
Putumayo	Colombia, Ecuador, Peru, Brazil: Putumayo, Caquetá, Napo, Alto Solimões, Huallagas Rivers

[1]There are no western macrocarp populations.

characteristics that were specific to them. In general, this phenomenon occurs with greater frequency in localities associated with urban centres, but occasionally it affects more extensive regions.

Genetic erosion and conservation. The reasons for the decline in importance of this crop are also responsible for the accelerated genetic erosion being sustained by its germplasm. To these should be added the expansion of some towns in whose surroundings interesting peach-palms are to be found, such as Yurimagua, with its spineless variety, and Iquitos in Peru; and also the deterioration in the social organization of small communities which is threatening their very existence, as is the case of the Yuvineto settlements of the Sequoya tribe – situated on a small

TABLE 9 Peach-palm gene banks

Country	Locality	Institution responsible	Approximate number of accessions
Brazil	Manaus	INPA-CENARGEN/EMBRAPA	450
Colombia	Buenaventura	Departamento de Agricultura y Fomento del Valle	400
	Araracuara	Corporación de Araracuara	100
	San José, Guaviare	Corporación de Araracuara	100
	Leticia	ICA	–
	Florencia	ICA	–
Costa Rica	Guápiles	UCR, CORBANA, MAG	950
	Turrialba	UCR	50
	Turrialba	CATIE	400
Ecuador	Napo-Payamino	INIAP	322
Nicaragua	El Recreo	MIDINRA	36
Panama	Las Pavas	IDIAP	54
Peru	Iquitos	INIPA	200
	Yurimaguas	INIPA	144

tributary of the Putumayo river in Peru – who have bred a local variety which is exceptional for its vigour, total absence of spines, large fruit and racemes and excellent table quality; and of the Guatuso in Costa Rica, a community of the Maleko tribe, which also developed a good-quality, spineless cultivar. These situations are not exclusive to the examples mentioned, but are fairly widespread in all the countries contained within *B. gasipaes*' distribution area. In Costa Rica, for example, it is possible to predict the extinction of the peach-palm within a few decades unless there is a resurgence of interest in its cultivation.

Populations of wild peach-palm are also threatened with extinction: *B. insignis* in Bolivia; *B. ciliata* in Peru; *Bactris* sp. (*chontilla*) in western Ecuador; *Bactris* sp. in Darién, Panama; *B. macana* in Venezuela; and *B. chantaduro* (?) (*chinamato*) in Colombia.

The collection and inclusion of germplasm in *ex situ* banks is one of the most important immediate measures to be taken and significant efforts have been made in this connection, especially in Costa Rica, Brazil, Colombia, Peru and Ecuador through self-funding and funds provided by international agencies.

Cultivation practices

Several products are obtained from the peach-palm, with the result that specific agronomic technologies have emerged for their exploitation. In fact, they are different crops. We shall deal here with the general aspects of two of these crops exploited on a commercial scale: palmetto and fruit.

Palmetto production. The seed beds are set up using soil beds or closed polyethylene bags. In the latter case, the seed's moisture content must be approximately 40 percent. A germination rate of 75 percent is achieved in soil beds and 90 to 100 percent in plastic bags. At ambient temperature (24 to 25°C) its germination begins in

1.5 months and may be regarded as being over at three months. Two asexual methods of propagation are currently being developed: tissue culture and culture from shoots; with both of these, however, there are difficulties which have still not been overcome. The newly germinated seedlings are taken from the seed bed to the nursery and at three to six months are planted out in the field. Transplanting can be done with soil or with bare roots. Planting density is 2 × 1 m or 1.5 × 1.5 m, and the number of shoots with which the rootstock is used is four to six. Depending on the size of the seedlings at transplanting and on soil fertility, the stems are ready for harvesting when they measure approximately 9 cm in diameter, which they attain 12 to 18 months after transplanting.

The first harvest is one stem per rootstock but from then onwards, if the plot is well managed, there may be an average of three or more stems per rootstock per year. The annual industrial yield, which is guided by current quality standards for canned palmetto, is approximately 1 tonne per hectare.

Because of the heterogeneity in the ages of the shoots, the population is composed of stems at all stages of development, which means harvesting must be done by hand. This consists of cutting the apical sector of the stem, removing the foliage and some of the sheathes covering it, and leaving two of them to protect it during transportation to the industrial plant. Harvesting produces a great amount of organic residue and, as it is done throughout the year, it contributes to the maintenance of an organic cover on the soil.

One hectare of palmetto produces 19.5 tonnes per year of dry matter, of which the extracted crude palmetto represents only 1.76 tonnes, i.e. 9 percent of the biomass produced.

The most important routine operations are the establishment of a drainage system before sowing and, subsequently, weed control, fertilization and pruning excess shoots. Regarding the latter, there are cultivars that frequently do not produce sufficient shoots or do not produce any at all, and this is a serious drawback. Putumayo is characterized by such behaviour.

No pests or diseases of any economic importance have yet occurred in plantations of peach-palm palmetto. Those that do appear occasionally are due to poor handling conditions. However, as in any crop, these will appear as the cultivation area grows. Peach-palm palmetto is a perennial crop which is constantly renewed through the shoots. The oldest plantation is 18 years old and continues to produce efficiently.

Fruit production. Seed germination and shoot production is the same as described for palmetto production. However, in this case it is more important to plant shoots in polyethylene bags or another type of container that allows the young plant to grow for nine months so that it can then be taken to the field when it is larger.

In cultivation for fruit production, the plants must attain their full development. The root system is therefore bigger and, because of this, greater drainage depth is required. The sowing densities chiefly adopted are 5 × 5 m and 4 × 4 × 8 m, with one or two stems being left on the rootstock.

An important aspect is the management of shoots with the aim of renewing old stocks. These must be handled in such a way that they are never absent, i.e. they must be cut before the bare stem appears because at that stage the axillary buds of the rhizome, which constitute the basic source of shoots, will have died. Shoot production is induced by eliminating apical dominance.

Harvesting the fruit is the most difficult operation of all crop management practices because of the height reached by the stems. For this reason, the stipes must be renewed when they reach heights which make the collection of racemes too difficult, i.e. at ten to 12 years of age. To prepare for its renewal, a shoot is allowed to grow for one year or 18 months before the removal of the stem in question, which is done after harvesting. The shoot will begin to produce in the following harvesting period.

Exploitation of the peach-palm for fruit production brings with it pests and diseases of greater economic importance than in the case of palmetto. The most serious disease is *Monilia* sp., which attacks the fruit and is at its worst during the more humid years, especially if drainage is deficient or planting very dense. The most destructive pests are parrots, which attack the fruit. These birds, which like the fruit when it is still green, appear in huge flocks and cause considerable damage.

Production per hectare is variable, depending on the cultivar, ecological conditions and management. Under good management, plantings with cultivars of the varieties Utilis, Putumayo and Sollimões produce approximately 25 tonnes per hectare in a year of normal climatic conditions. As soon as the selections obtained can be reproduced by cloning, the yield per hectare will increase considerably.

Prospects for improvement

Except in Brazil, where current domestic consumption is much greater than in the rest of the world, the palmetto is an export product, although its international market is still small (approximately 20 000 tonnes per year). In this area it has to compete with the *Euterpe* palmetto, extracted from the forests, and which, at present, meets approximately 85 percent of international demand (Brazil's domestic consumption of palmetto from this other palm exceeds 100 000 tonnes per year). However, because of its greater productivity and because of world conflict over related ecological issues, it is envisaged that the cultivated peach-palm will gradually replace the *Euterpe* palmetto. The following may be mentioned as factors limiting the peach-palm's development:

- The lack of commercial availability of highly productive varieties suited to the various ecological conditions and having the appropriate quality for various industrial uses.
- The absence of an efficient asexual reproduction method that enables commercial propagation of the selections obtained; in recent years, intensive work has been carried out to solve this problem at the UCR, at INIPA, in Iquitos, Peru, and at the University of São Paulo, Brazil, but the solution does not seem to be within sight.
- Deficient or non-existent industrial techniques for processing peach-palm products.
- Limited economic resources to stimulate cultivation.
- Unfamiliarity with peach-palm products on the market.
- Scant economic resources assigned to research to solve the first three aspects and maintain a constant control over production techniques and to overcome particular problems that occur.

Financial limitations aside, the prospects for improvement are very promising from the agronomic, industrial and marketing points of view.

In genetic improvement, for the production of high-yielding varieties, the gene banks contain plants that have a very high fruit yield, and others that show great vigour and earliness for palmetto production.

Using normal plant improvement methods, this limitation can be overcome. Several gene banks have already evaluated – at least partially – the accessions and have selected highly productive and good-quality plants for certain uses. As far as their evaluation under different ecological conditions and their subsequent distribution to farmers is concerned, the difficulty is the absence of an asexual reproduction method enabling clonal populations to be obtained.

The same process and difficulty are involved in the second stage of the use of hybridization to bring desired characteristics together and exploit the possible expression of heterosis.

The scant research which has been carried out in the industrial sphere is also a limitation. In the case of palmetto, work has only been done concerning canning problems, without concentrating on other possible uses such as dried or liquid soups, packs for fresh palmetto, toasted palmetto (crisps), etc., which offer potential for broadening the market. Palmetto is a suitable product for modern diets, as it is rich in fibre, tasty and, when dry, a nutritional product. Industrialization of the fruit has demonstrated its nutritional value (as a source of energy, beta-carotene, oil and other nutrients) for human consumption and as animal feed. The range of products that can be prepared with the fruit is similar to that prepared with various grains. Industrialization has barely begun, but it does not seem to pose any major technical problems. Its limited development is the main difficulty that normally faces a new product on its introduction to the market, a process which requires costly promotion and generally long-term investment.

The geographical regions suited to this crop are very extensive in all the countries of the American tropics and outside the continent. Even in small countries such as those in Central America, hundreds of thousands of hectares are suitable; for example, in Costa Rica these have been estimated as totalling 700 000 ha. The cropping technology is adaptable to any scale.

Lines of research

The most pressing research requirements to raise peach-palm cultivation to a competitive level on international and local markets are as follows:

- concluding exploration work in territories spanned by the geographical distribution of the species;
- establishing an inter-American network of gene banks;
- evaluating accessions in a programme common to all the banks;
- studying the taxonomy of the complex in greater depth;
- developing reproduction techniques using tissue culture and shoots;
- developing a method for the long-term storage of seed;
- setting up comparative trials on varieties and confirming the results on a commercial scale;
- studying integral methods of weed, disease and pest control;
- establishing the critical levels of the various chemical elements required;
- diversifying the industrial products of the fruit and of the palmetto;
- continuing studies on the use of the fruit for human consumption and as animal feed;
- carrying out market research for the various products;
- studying and encouraging the organization of peasant producers in associations;
- studying the social and ecological impact of the crop and its industry.

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Species of *Paullinia* with economic potential

GUARANA
(*Paullinia cupana*)

Botanical name: *Paullinia cupana* H.B.K.
Family: Sapindaceae
Common name: guarana

Guarana is undoubtedly among the stimulants that are attracting most attention from the developed countries nowadays. All kinds of qualities are being attributed to it, from that of being a simple stimulant to an aphrodisiac, and it is now a must in the herbalist's shop. It was already cultivated at the time of the discovery and, from the seventeenth century, its seed occupied a prominent place among the products used for local consumption and export in the region of Manaus in Amazonia. According to one missionary, certain Indian tribes valued it in the same way as "the whites valued their gold". The use of guarana in Europe was documented in 1775, but information on its production up to the beginning of this century is very uncertain. The only information available for last century relates to the export of 262 *arrobas* (1 *arroba* = 11.5 kg) to Europe in 1852.

In 1923, the harvest was 3 873 kg. After a harvest of 124 000 kg in 1935, since no exports took place and domestic consumption had gone down, there was a surplus of guarana which led the government of the state of Amazonas and the producers to form the Emporio de Guarana, which was granted the marketing monopoly of the product. As from 1966, with the winding up of the Emporio, which served more as a stagnating than development factor, an industrial system for the product began to be established. The aggressive internal and external publicizing policy for guarana, adopted by the government and begun at the end of the 1940s, led to the present situation where demand is several times greater than supply.

Both official records and socio-economic studies indicate that there were two main production phases: the extraction or collecting phase, which extended up to the 1970s, and the cultivation phase from that time on.

Uses

Guarana is used mainly to produce a soft drink. For a long time, it was used empirically in medicine; it is attributed antipyretic, antineuralgic and antidiarrhoeal properties and is reputed to be a powerful stimulant, an analgesic comparable to aspirin and an anti-influenza agent. The seeds contain 2.7 to 3.5 percent caffeine as well as theophylline and theobromine. The traditional method of using guarana (the only one until the 1950s and one that is still widespread nowadays) is as follows: when the fruit has been harvested, the seeds are separated and stored until fermentation of the aril, which is then removed. They are then roasted and their seed coat is removed; this is marketed as "guarana *en rama*", i.e. raw guarana. The remaining seeds are immersed in water to form a paste. From this are made sticks which,

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after being dried over a slow fire and smoked for one month, are marketed. The traditional way of preparing the drink consists of grating part of the stick in water to produce an infusion. The guarana carbonated drinks industry began in 1907 and the product became Brazil's national drink during the 1940s. In 1973, the Law on Juices laid down regulations for the use of guarana, defining the maximum and minimum concentrations for carbonated drinks, syrups and other products. In 1981, EMBRAPA's Agricultural Research Centre of the Semi-Humid Tropics (CPATU) developed soluble guarana. Nowadays, guarana is marketed as sticks and soluble or insoluble powder and is used industrially for the production of carbonated drinks, syrups and herbalists' products.

Botanical description

Guarana is a scandent shrub or woody liana. Its leaves are alternate with five folioles and, when tendrils exist, they are axillary. The inflorescences are on axillar racemes or originate on the tendrils. The flowers are male and female, zygomorphous and have five petals and sepals, eight stamens and a trilocular ovary with a glandular semi-disc at the base. The fruit occurs in a septicidal capsule, it is orangey-red and partially open when ripe, revealing one to three black or greenish seeds which are covered at the base with a white aril. The var. *cupana* differs from the var. *sorbilis* in that it has no tendrils, its folioles are more strongly lobed and its flowers and fruit are bigger.

Guarana is a monoecious, allogamous species. It is fertilized by bees of the genera *Melipona* and *Apis*. It is probably dispersed naturally by birds, although the distances to which it can be disseminated are not known. Its seeds are recalcitrant and lose their viability in 72 hours under normal conditions. Germination can take more than 100 days.

Ecology and phytogeography

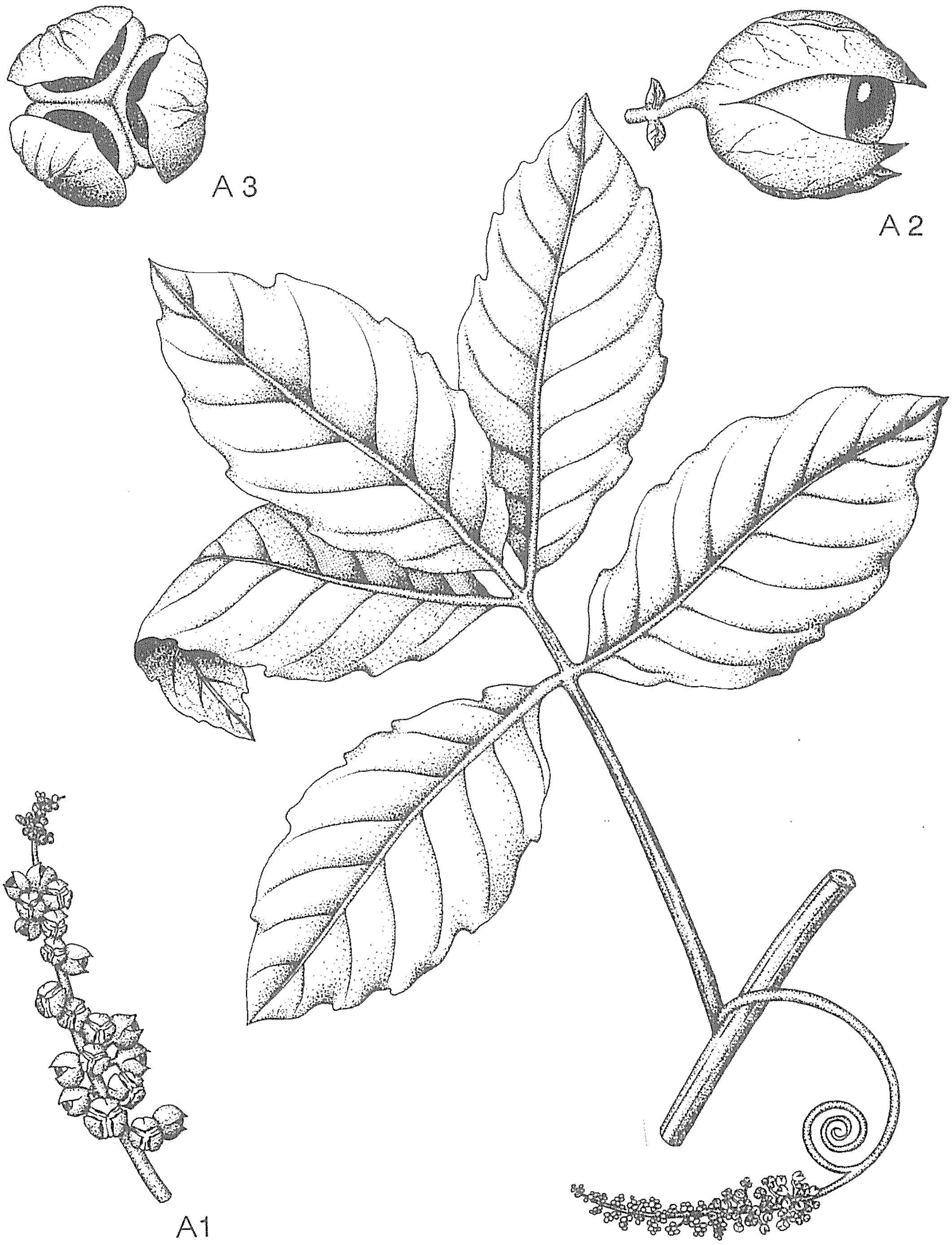
The genus *Paullinia* is predominantly neotropical, extending from Mexico and the southern United States to Argentina. A single species, *P. pinnata*, is found in both America and Africa.

The soils in which it is found in the native state are generally gley soils or dystrophic lateritic soils. The climate of the region of origin is Am in Köppen's classification, with an annual precipitation of approximately 2 200 to 2 500 mm. The temperature is isothermal, with an annual mean of 28 to 29°C.

The var. *cupana*, on the basis of which the species was described from material collected by Humboldt in San Fernando de Atabapo, Venezuela, is known only in the area between the south of the Atures and Maipures torrents of the Orinoco River and in the region of the upper Negro River and tributaries on the frontiers between Brazil, Colombia and Venezuela, where it seems to be relatively common. It is used by the natives of the Mapiripán region on the Guaviare River in Colombia. The var. *sorbilis*, or true guarana, seems to have been domesticated in the southern strip of the Amazon River between the gorges of the Purús and Madeira Rivers. From the middle of the last century, it was cultivated in what are now the municipalities of Borba, Maués, Parintins, Manaus and Itacoatiara, and these continue to be the most important centres for the cultivation and distribution of material for other localities. The geographical disjunction between the two varieties has been attributed to anthropic factors; according to this hypothesis, the species was domesticated in the Maués region from a woody liana which reaches the forest canopy. Both the plant and the way of eating it were introduced to the upper Negro River area by the Barrés (or Barés), who gradually migrated north. Domestication of the species must have been very old to enable the formation of a new variety. According to this hypothesis, the var.

FIGURE 25

A) Guarana (*Paullinia cupana*); A1) inflorescences on the raceme; A2) fruit in the capsule; A3) trilocular ovary



cupana is a subspontaneous form derived from domesticated guarana. Regarding the existence of guarana in the native state, some information available suggests that, even today, the Maués Indians are introducing wild material into their crops in spite of the fact that it has been stated that guarana is known only in cultivation. Its presence outside the areas mentioned is poorly documented. A specimen collected at the Curuquetê River, on the border between the states of Amazonas and Acre (Brazil), seems to be *P. cupana*, and there are also reports that it grows spontaneously around Santarém in Pará. The same thing is happening in the case of guarana as has happened with other cultivated species: botanists are ignoring them because they are not taxonomically new.

Paullinia yoco, the other species used as a stimulant, is only known in the wild state and is distributed in a relatively small region along the Putumayo River on the frontier between Colombia and Peru.

Genetic diversity

There are two varieties of *Paullinia cupana*. There is no information on the genetic variability of the var. *cupana*, which is little known and little studied.

P. cupana var. *sorbilis* shows a high degree of variability. It grows mainly in the planted fields of small producers in the municipalities of Maués, Parintins and Borba in the state of Amazonas. EMBRAPA has a valuable collection located in the experimental field of Maués and a gene bank with more than 200 accessions in Belém (CPATU). There is also a working collection at the CPAA/EMBRAPA in Manaus, with over 700 accessions. There appears to be no risk of genetic erosion, since both the agricultural research system and the producers are aware of the value of the material in their possession. The closest wild species belong to the *Pleurotoechus* section of the genus. There are nine species of it in Brazilian Amazonia, all with certain morphological resemblances to *P. cupana*. The closest taxon is *P. cuneata*, which may belong to the same species (*P. cupana*). This, together with *P. yoco*, merits special attention for possible improvement programmes. The areas of greatest interest for prospecting are the basin of the Putumayo River (*P. yoco*) and the frontier area between Brazil, Peru and Bolivia (the Madre de Dios river basin), where *P. cuneata* and a species which may be a wild form of *P. cupana* are found. Also of great importance is the upper Negro River, including considerable portions of the Amazonia and Orinoco regions of Colombia and Venezuela. Nowadays, the var. *cupana* is considered to be of possible fundamental importance for the improvement of guarana.

Cultivation practices

Traditional cultivation of guarana is carried out with full exposure to sun on soils with a low fertility (exchange capacity of 20 to 40 ppm), a low acidity (pH between 3.5 and 4.5) and with high concentrations of aluminium. Fertilizers are not used. Spacing of the plants is approximately 4 × 5 m, which gives 500 plants per hectare. After the second year, pruning is carried out to remove old and diseased branches and those which flowered the previous year. Since 1980, a new type of management has been adopted, using the same layout but with fertilizers and pruning to direct the branches along supports. According to technical recommendations, guarana must be grown in areas with a climate similar to its region of origin, with a mean annual temperature between 22 and 20°C. The minimum temperature tolerated is 12°C. Annual precipitation must exceed 1 400 mm, with rain well distributed during the year. Soils must be deep, medium or heavy in texture, well drained and with a high organic matter content. Traditional planting is by sowing: the oldest plantations are very heterogeneous both from the genetic and the phenotypical points of view. Prominent among the more modern techniques is propagation from cuttings, for which misting chambers, grafts and tissue culture propagation need to be used.

The average production of the harvesting phase (1938 to 1970) was 175 tonnes per year, with many fluctuations. In the last five years for which cultivation data are available (1983 to 1987), the average was a little over 1 200 tonnes per year, with about a sevenfold increase over the former statistics. Although an extension of the cultivated area influenced this increase, the rise in productivity per hectare also made a substantial contribution, its average almost doubling between the first five years of the 1970s and the last five years recorded, with averages of 71.5 and 137.8 kg of seed per hectare, respectively. This increase in production can easily be attributed to the new type of management, since in field experiments production data were obtained for the traditional system (79 kg per hectare) and improved system (130 kg per hectare) which were very similar to the averages referred to.

As may be seen, Brazil's production is increasing considerably. Until the mid-1970s, the state of Amazonas was the only producer; in the last ten years, other states have begun to produce guarana, notably Bahia and Mato Grosso. In 1987, Bahia's production exceeded that of the state of Amazonas for the first time.

Outside Brazil, other countries are beginning to produce guarana. However, there is little information available. In the great majority of cases, cultivation is beginning with a very limited genetic base, since Brazil does not authorize the export of seeds or vegetative material.

Prospects for improvement

Undoubtedly the biggest limitation today is low productivity, since an average yield per individual ranges between 250 g (traditional cultivation) and 520 g (improved management) of dry kernel and therefore still leaves much to be desired. In part, this problem is strictly agronomic and will be resolved once plantings are carried out under more favourable conditions.

The selection of more productive early material that is resistant to disease and stress – a process begun in Manaus as early as 1980 – will be bound to lead to an increase in productivity, since individuals have been identified in experimental and commercial plantings with yields of between 4 and 6 kg of dry seed per hectare per year. The production of hybrids, either through traditional methods or using genetic engineering techniques, will also be of great importance, especially in conjunction with the production of clonal material which allows more uniform treatment and management to be achieved. The genetic basis for these improvement programmes already exists, not only within the available genetic stock of guarana but also of *cupana*, and possibly in other species of *Paullinia* such as *P. yoco* and *P. cuneata*. The potential market for 1983 was estimated to be around 16 000 tonnes and has increased since that year. The shortfall of guarana is around 10 to 15 times the current production volume, which still allows a considerable expansion of cultivation.

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Subtropical Myrtaceae

JABOTICABA
(*Myrciaria* spp.)

Botanical names: *Myrciaria cauliflora* Berg., *M. jaboticaba* Berg., *M. trunciflora* Berg.

Family: Myrtaceae

Common names. *English:* jaboticaba; *Spanish:* jaboticaba; *Portuguese:* jaboticatuba sabará, jaboticaba murta, jaboti-catuba, jaboticatuba grande, jaboticaba olho-de-boi, jaboticaba-de-cabinho (Brazil)

Among the Myrtaceae, various species of the genera *Psidium, Eugenia, Feijoa, Myrciaria, Campomanesia* and *Paivaea* stand out which are native plants of neotropical flora and produce fruit of commercial value. Jaboticaba, which has been cultivated in Brazil since pre-Columbian times and is much in demand in the centre and south of the country, is a promising fruit of this family. It is grown in small commercial gardens of 500 to 1 000 trees and in domestic gardens.

Uses

Jaboticaba is eaten fresh and is known on account of its outstanding qualities, having an abundance of juice and a particularly sweet flavour. It is used industrially for jellies and to prepare domestic liqueurs and wines. It must be consumed immediately after harvesting, since it does not keep well at ambient temperature and lasts no more than three days.

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Botanical description

The jaboticaba is a tree of medium habit, not exceeding 12 m in height, with a voluminous and symmetrical crown, one or more trunks and many branches. The leaves are ovate or lanceolate, 5 × 2.5 cm, smooth and shiny. The flowers occur in short racemes which emerge from the trunk, from the ground and on the main branches; there are four white petals and numerous long stamens.

The fruit is a spherical berry, 2 cm in diameter in the Sabará variety and 3 cm in the Jaboticatuba. It is grouped in racemes of three to seven, is red initially and shiny black when ripe. Sabará is the best variety; it produces polyembryonic seeds and the majority of the embryos are apomictic, while Jaboticatuba is monoembryonic with zygotic embryos. During flowering in spring, particularly in areas with dry winters, the tree flowers abundantly with the first rainfall, giving the impression that the trunk is covered with snow.

Ecology and phytogeography

As a subtropical, deciduous species, jaboticaba is frost-tolerant. In tropical conditions it does not flower as abundantly as in the areas where the winter is cold and dry. Flowering can be brought forward with irrigation, but the flower buds must already be developed. From ten to 20 days elapse between flowering and fruiting. Fruiting is very short and harvesting does not exceed two weeks.

The species is distributed from lat. 21°S in the state of Minas Gerais to Rio Grande do Sul, at lat. 30°S, always at altitudes higher than 500 m. It grows best in groups, on deep, acid and fertile soils. However, there are wild populations which have withstood the felling of forests in Minas Gerais, São Paulo and Rio Grande do Sul.

Genetic diversity

The most widespread species, *Myrciaria cauliflora*, produces apomictic embryos and, for this reason, shows very little genetic variability, while the zygotic species, Jaboticatuba, shows much variation but is a much rarer plant. Other *Myrciaria* species are little known.

Propagation and cultivation techniques

The preferred method of propagating jaboticaba is from the seeds, which are recalcitrant and not resistant to desiccation. They are sown 10 cm apart in a fertile seed bed, with 30 cm between the rows, where they remain for one year. When they are 10 to 15 cm high, they are transplanted to the nursery with a rootball and spaced 1 m apart with 2 m between rows. They stay in the nursery from three to five years and, when they reach 1.5 m in height, are planted out in the garden with the rootball measuring 60 cm in diameter. The plant's growth is slow. It is planted out at 6 × 6 m or 6 × 4 m, and it does not matter if the crowns are close together.

Various vegetative propagation techniques are used to obtain earlier plants, mainly through root cuttings, layering and grafts. However, the tree's development is always slow. In this species it is advantageous to have the greatest area of trunk and branches from which the fruit emerges. Since early production delays the plant's development, the only advantage of vegetative reproduction would be the possibility of planting at a greater density, such as 4 × 2 m.

Prospects for improvement

There is no advantage in the genetic improvement of jaboticaba. However, crossing Jaboticatuba, which produces large fruit and zygotic embryos, with the cultivar Sabará, which is of better quality but produces smaller fruit could be recommended. As 100 percent of hybrids would be obtained, it would eventually be possible to obtain selections of jaboticaba bearing large fruit of better quality.

ARAZA
(*Eugenia stipitata*)

Botanical name: *Eugenia stipitata* McVaugh
Family: Myrtaceae
Common names. *English:* arazá; *Spanish:* arazá (Peru); *Portuguese:* araçá-boi (Brazil)

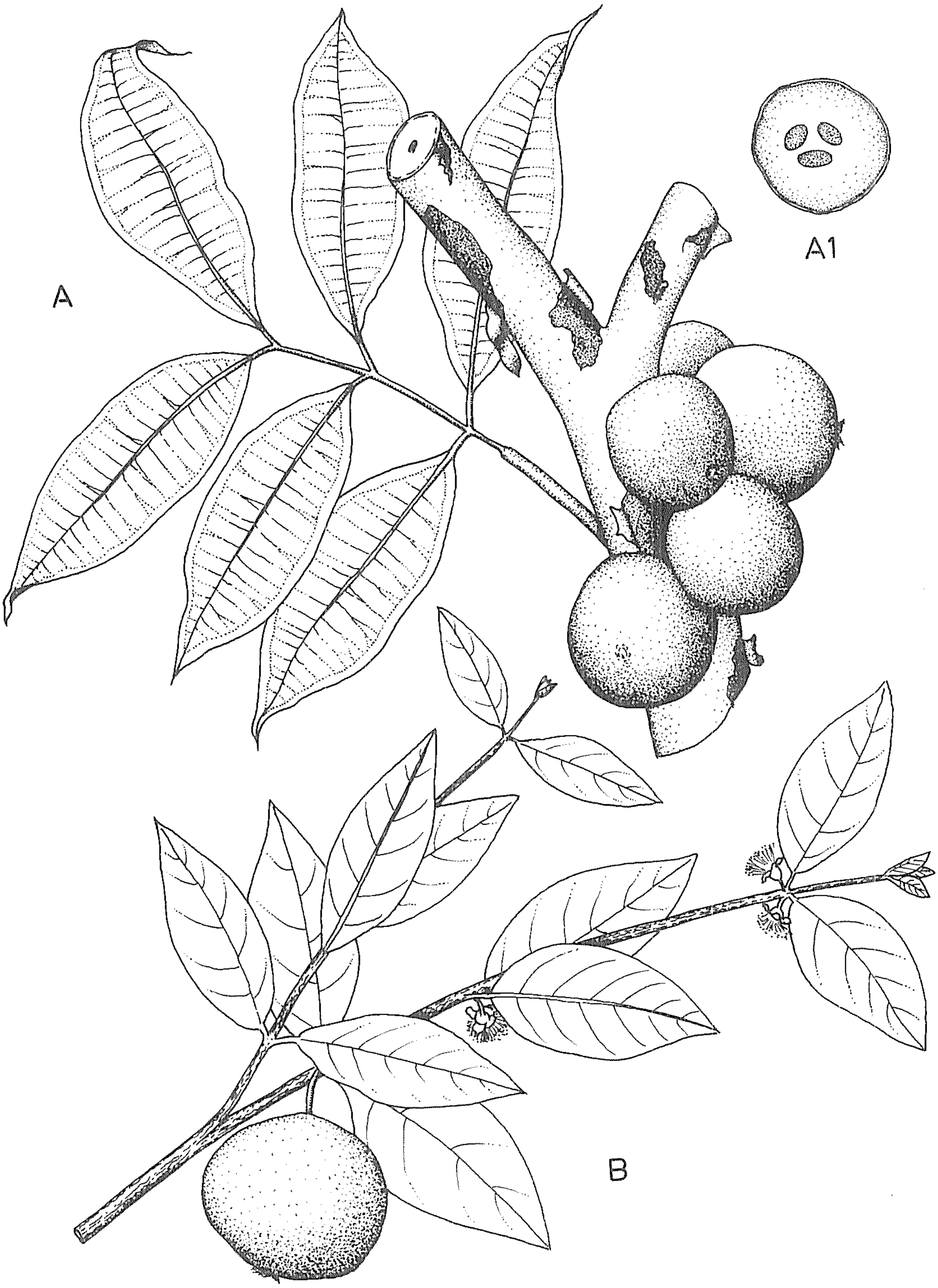
Eugenia stipitata includes two subspecies: *stipitata*, from the state of Acre in Brazil, and *sororia*, which is more widely distributed from the basin of the Ucayali River in Peru. The latter seems to have been semi-domesticated in western Amazonia, although it may have originated in the southeastern portion of Amazonia. The arazá must have undergone a long process of selection by the Amerindian communities, as can be deduced from the large size of the fruit which, within the cultivated material, can be as large as 12 cm in diameter and 740 g in weight, compared with the wild populations which do not exceed 7 cm in diameter and 30 g in weight.

The species is still in the full process of domestication. The two institutions which have worked most on this fruit are INIAP's experimental station of San Roque in Iquitos, Peru, and INPA in Manaus, Brazil.

Today, the arazá is cultivated on small properties throughout the basin of the Solimões (Alto Amazonas), not as a commercial crop but as part of the complex mosaic of crops characteristic of the traditional agriculture of the region. It is relatively common on the town markets of Tefé, which is midway between Manaus and Iquitos.

FIGURE 26

A) Jaboticaba (*Myrciaria* spp.); A1) cross-section of the fruit; B) arazá (*Eugenia stipitata*)



Uses and nutritional value

Arazá is used to make juices, soft drinks, ice-cream, preserves and desserts. The fruit is rarely eaten raw because of its acidity (pH 2.4 in the case of the juice). Unlike camucamu (*Myrciaria dubia*), more than 20 percent of whose fresh weight is represented by 2 percent of ascorbic acid, arazá's potential is due to its intrinsic characteristics as a fruit: pleasant flavour, colour, texture and smell.

The nutritional value of arazá is very similar to that of oranges, with the exception of the vitamin C content which is more than double in arazá.

Botanical description

The arazá is a shrub or small tree which grows up to 2.5 m, with a fair degree of branching from the base. The leaves are simple, opposite, elliptical to slightly oval and measure 6 to 18 × 3.5 to 9.5 cm. The apex is acuminate, the base rounded to subcordate and the primary and secondary nervations are fairly evident. The inflorescences are in axillary racemes, usually with two to five flowers which are 1 cm wide and pedicillate, have four rounded sepals and five white, oval petals. There are numerous stamens and an ovary with three or four locules. The fruit is a subspherical berry, reaching 12 cm in diameter and weighing 750 g when ripe; the flesh is yellow and thin; the skin is shiny, velvety and yellow, with few seeds which are oblong and measure up to 2.5 cm.

The subspecies *stipitata* has fewer stamens and an arboreal habit, whereas the subspecies *sororia* has a shrub habit and has more stamens.

Ecology and phytogeography

The arazá is a species of semi-open or open areas. Most of the wild populations are found on old, non-floodable terraces in tropical, white, highly leached podzolic soils, which are distributed specifically within the area between the Marañón and Ucayali Rivers and where the Amazon begins and as far as Iquitos (ssp. *sororia*). The camucamu and arazá have sclerophyllous leaves, which makes them very efficient in absorbing nutrients and utilizing water.

It is not surprising that the arazá can produce between 20 and 30 tonnes of fruit per hectare annually without any great selection or improvement effort and that, under cultivation on Amazonian terraces, it is more productive than the camucamu.

Although there are no detailed studies on its reproductive system, on the basis of its floral morphology, the species must be allogamous with optional autogamy, since rates of autogamy of around 2 percent are recorded. This would enable it both to maintain a high evolutionary potential and have some degree of adaptation to its environment.

The species is harvested several times a year. If a comparison is made of the production curves of flowers and fruit with precipitation during the same period, it will be seen that they coincide fairly well with an out-of-phase period of approximately one month, which suggests that the water conditions serve to promote the phenological processes.

Genetic diversity

No data are available on the genetic variability of the arazá. The fact that it shows optional allogamy suggests that it has a high degree of heterozygosity which corresponds to what is expected of the majority of the species of the region.

Dispersal over a long distance is probably effected by birds and possibly fruit-bats, with very variable dispersal distances, thus allowing an exchange of genes between distant populations. There is likely to be a bigger difference within one and the same population than between populations. However, the fact that two subspecies exist in relatively restricted areas suggests that dispersal over a long distance is not very effective and that there are barriers to its distribution which are difficult to explain from the ecological point of view. Genetic variability does not seem to be in danger. However, there are only two collections of germplasm: that of San Roque, with 50 accessions, and that of INPA, with five accessions.

Cultivation practices

Seed beds. The seeds are recalcitrant and, after 40 days in cold storage, they lose more than 70 percent of their viability. Consequently, seed beds must be established in the first five days after the seeds have been harvested.

The seed beds are kept completely in the shade; the seeds are planted 2 cm apart and only lightly covered, as greater coverings inhibit germination. As a seed bed, partly decomposed softwood is recommended while the use of earth is not advised. Germination is not uniform and may take up to 80 days; in the conditions described, the germination rate may reach around 100 percent.

Nurseries. The seedlings are kept in the seed bed until they reach a height of 7 to 10 cm. They are then transplanted into 6 to 8 kg polyethylene bags filled with a mixture of earth and 10 percent manure. The plants stay in the bags for up to one year; six months in the shade and 6 months in partial shade.

Planting out. After one year, the plants are planted out on their final site. In San Roque, distances of 3 × 3 m have been adopted, with holes measuring 50 cm deep and 30 to 50 cm in diameter. The soil is mixed with 0.50 kg of manure. It is recommended that weeds be eliminated from the planted area each month and organic material added to the soil. Experimental results on fertilization suggest that organic fertilizer with manure is preferable to chemical fertilizers.

In Amazonia, it is recommended that chemical fertilizers not be used since their possible effect on the environment is unknown. In addition, the cost of these applications may make the crop economically unviable. In fertilization trials, chemical fertilizers had no influence on fruit formation (between 20 and 40 percent, average 25 percent) or on the total yield, which justifies not recommending its use in the region.

Prospects for improvement

It is difficult to predict the upper limits of arazá production, as it is still in an early phase of domestication. The genetic base is not known and knowledge about management practices is so limited that it is impossible to make realistic projections. Undoubtedly, under suitable cultivation conditions, its productivity may be somewhat higher than at present while its cultivation in other regions may amply justify chemical fertilization.

There do not appear to be any serious plant health problems. The species suffers heavy attack from the fruit fly, which reduces the normal density of plantings if sophisticated biological control measures are not adopted.

The success of arazá as a widespread crop will depend above all on technological developments that facilitate its acceptance on markets outside the region. Any improvement or selection programme will have to involve parameters such as appearance, colour, smell, palatability and resistance of the fruit to transportation and storage.

FEIJOA
(*Feijoa sellowiana*)

Botanical names: *Feijoa sellowiana* O. Berg, *F. sellowiana* var. *rugosa* Mattos
Family: Myrtaceae
Common names: feijoa (throughout the world); *English:* feijoa (throughout the

world), pineapple guava (United States);[1] *Spanish:* guayabo grande, guayabo chico (Uruguay); *Portuguese:* goiaba serrana, goiaba verde, goiaba abacaxí (Brazil)

The feijoa is a subtropical fruit, known in southern Brazil, northeastern Argentina, Uruguay and eastern Paraguay since pre-Hispanic times. It has been known on the French Côte d'Azur since 1890, when it was introduced through seeds from Argentina by Professor Edouard André of the Versailles School of Horticulture. In 1990, it was introduced into California, where its cultivation has spread. In Uruguay, it has been grown commercially for 50 years. It is grown and greatly valued in New Zealand. In Brazil, studies and the selection of varieties have been carried out but it has never attained any commercial importance.

Uses

The fresh fruit is widely consumed because of its characteristic flavour and aroma, which are similar to pineapple. The fleshy petals of its beautiful flowers are also appreciated. In addition, there is a wide variety of industrialized products on the market in the form of paste, jam, crystallized fruits, preserves in syrup and liqueur. The flesh can be used in the soft drinks and ice-cream industries.

Botanical description

The feijoa plant is a shrub or small tree, 3 to 5 m in height and very branching. It has cylindrical trunks which are a reddish ash-grey in colour, with small pieces peeling off from the bark. The leaves are opposite, short petiolate, with lamina that are 2 to 5 cm long by 1 to 3 cm wide, coriaceous and oblong, with a shiny dark-green upper surface and whitish lower surface. It has axillary uniflorous peduncles. The flowers have four fleshy, oval petals which are white on the outside and purple on the inside, with four persistent sepals. There are numerous erect purple stamens. The fruit is oblong or spheroid, 5 to 8 cm long and 3 to 7 cm in diameter. There are smooth or rough varieties of fruit which are green and yellow in colour. The feijoa flowers in spring and the fruit ripens in autumn from March to May in the Southern Hemisphere and from October to December in the Northern Hemisphere. The early varieties ripen in March, while the late varieties do so from April onwards in the Southern Hemisphere.

Ecology and phytogeography

The species is widely distributed in the southern part of South America, from lat. 26°S in southern Paraná in Brazil, to lat. 35°S in Uruguay, including northeastern Argentina and southern-central Paraguay. In Brazil there are still wild populations in forests (gallery) and deforested areas on sites at altitudes over 500 m, for which reason it is known as goiaba serrana or "mountain guava". It frequently occurs in the states of Santa Catarina and Rio Grande do Sul, in the *cima da serra*, upper northeastern coast and southwestern *serra* regions and in Santana do Livramento. At these sites, the summer is hot and rainy and the winter reaches temperatures of 0 to 8°C, sometimes dropping to -4°C.

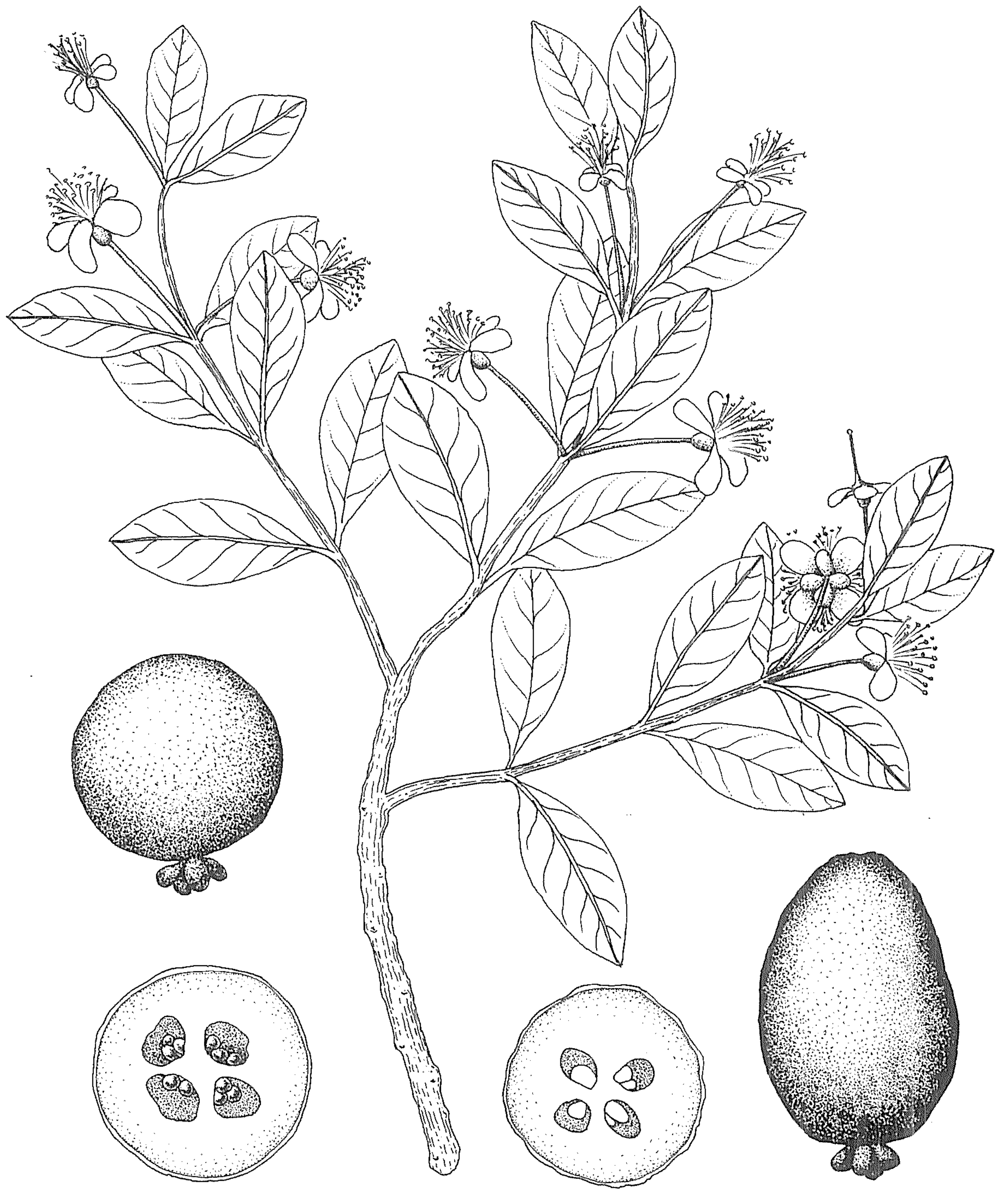
Genetic diversity

It is a cross-pollinated plant and self-sterility is frequent. However, there are self-fertile selections. When it has been propagated from seed, it displays great genetic variability, both in the wild and in gardens. Variability is shown in the form and habit of the plant and in the characteristics of the fruit. In Uruguay, 11 cultivars are known,

[1]The feijoa is frequently quoted in the literature as "araçá" but this fruit, also from neotropical flora, belongs to the genus *Psidium*, including many species, among which the guava.

FIGURE 27

Feijoa (*Feijoa sellowiana*), shapes and cross-sections of the fruit



prominent among these are: Botali, because of its size – the fruit measures 6.5 × 3.8 cm – its pronounced flavour and late ripening; and M-4, which is round, a beautiful reddish yellow colour and extraordinarily sweet. In Brazil, Santa Elisa and Campineira have been bred; the first is of average size, 4.5 × 3.5 cm, smooth, sweet and flavoursome while the second is ridged and also oblong. In California, Coolidge, Superb, Choiseana, Triumph and Hehre are cultivated. In France, André and Besson are of excellent quality.

Cultivation practices

Feijoas are propagated from seed, layering, cutting and grafting. Propagation from seed produces very heterogeneous plants. Consequently, this method is used only in the production of rootstock and in small domestic gardens. The seeds are recalcitrant and are therefore sown as soon as they are collected, either in seed beds, using the conventional technique, or directly into 30 × 20 cm polyethylene bags. They are transplanted into the nursery at a distance of 1 × 0.40 m until they reach a height of 60 to 80 cm, or are grafted with selected varieties. Layering is a tedious method, used for the production of a small number of plants.

Propagation from semi-ligneous, leaf-bearing, terminal shoots is very much to be recommended. They must be 10 to 15 cm long, treated with rooting hormones and placed in glass or plastic frames saturated with moisture. They put out roots in 15 to 20 days. The rooted cuttings are transferred into 30 × 20 cm polyethylene bags in which they remain for one year until they reach a height of 60 to 80 cm, at which stage they are planted in gardens.

Grafting is by a side graft on rootstock existing in the nursery or in polyethylene bags. The technique is known as "Veneer" grafting. When the young plants from a grafted cutting reach 60 to 80 cm in height, they are transplanted into the garden at a distance of 6 × 3 m or 6 × 2 m, which will give 550 to 850 saplings per hectare. With an average production of 1 000 fruits per adult tree and fruits weighing 30 to 60 g, these densities produce yields ranging from 16 to 50 tonnes per hectare.

Feijoa fruit is attractive to fruit flies, mainly *Anastrepha* sp., particularly in places with high temperatures in South America, and *Ceratitis capitata* in the Mediterranean and in high areas in South America.

The fruit is fairly resistant to transportation. However, for the fresh fruit market it requires special care from harvesting, packaging and cold storage to transportation. In industry it does not require such care, and even fruit that has fallen to the ground can be collected if it is unblemished.

Prospects for improvement

The green colour of the fruit of most of the known varieties is considered a drawback from the marketing point of view because it is not very attractive. For this reason, yellow and red cultivars are sought. Partial or total self-sterility is another problem that affects production. There is a need for self-fertile selections and studies on pollinating compatibility between varieties.

Feijoa cultivation can be expanded through the subtropical regions which do not have harsh winters, but this species needs to be better known, particularly its characteristics and cultivation conditions. The availability of germplasm may contribute to the expansion of this valuable fruit of neotropical flora.

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Guinea arrowroot (*Calathea allouia*)

Botanical name: *Calathea allouia* (Aubl.) Lindl.
Family: Marantaceae
Common names. *English:* Guinea arrowroot, sweet corn root (Caribbean) topeetampo, topi-tamboo, topinambour; *Spanish:* dale dale (Peru [Amazonia]), agua bendita, cocurito (Venezuela), lerenes (Puerto Rico), topitambo or tambu (West Indies), topinambur (Antilles); *Portuguese:* ariá (Brazil [Amazonia]), láirem (Brazil); *French:* touple nambours (Santa Lucía); alléluia, curcuma d'Amérique (France)

Guinea arrowroot or sweet corn root (*Calathea allouia*) is an oleiferous species which has been known and cultivated for a long time by the indigenous peoples of tropical America. It is sustaining a loss of genetic variability because its cultivation is increasingly being abandoned. In Brazilian Amazonia up to the end of the 1950s, Guinea arrowroot was a vegetable cultivated on a small scale by traditional growers in their vegetable gardens and the tuberous roots were eaten cooked, accompanied by coffee. At present, in communities further away from towns in Amazonia it is rare to meet a grower who still keeps Guinea arrowroot in his garden. For cultural reasons, it is precisely the indigenous populations who are continuing to grow the species.

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Distributed throughout the world, Guinea arrowroot has been well accepted, but has not reached the point of being an important crop anywhere.

In Brazilian Amazonia, its increasing abandonment seems to have been caused by two main factors: its very long vegetative cycle (ten to 12 months) and its replacement in the diet of small rural producers by other types of food (sweet potato, cará, yam or other industrialized products such as wheat biscuits and bread). Even in its region of origin where its cultivation dates back 1 000 years, Guinea arrowroot is at present used only in subsistence farming by traditional growers and indigenous populations.

The tuberous roots of Guinea arrowroot are eaten cooked and their texture remains crisp even after long cooking, a characteristic which makes it very palatable. It is cooked in water for 15 to 20 minutes and its flavour is similar to that of cooked green maize. As well as being eaten on its own, Guinea arrowroot can be an ingredient of salads, mayonnaise and fish dishes.

In South America, the leaf dye is used in traditional medicine to treat cystitis and as a diuretic. The fresh leaves are used to make baby clothing, as they are strong and durable.

Generally speaking, the prevailing climatic conditions in the humid tropics – relatively high temperature and humidity throughout the year – are unfavourable for the cultivation of vegetables from a temperate or subtropical climate and, at the same time, encourage the development of pests and phytopathogenic micro-organisms. It is in this context that the potential of little-known species should be evaluated. In the plantations of INPA in Manaus, no pest attacks or presence of diseases causing significant damage to Guinea arrowroot have been found during the last 15 years.

The study of agroforestry systems has intensified in recent years. These systems benefit from the techniques and plant species used by traditional and indigenous growers. They are thought to constitute land management methods which are more ecologically suited to the humid tropics. Guinea arrowroot is a vegetable which was grown in vegetable gardens for centuries, and historical evidence has shown the important part it played in agroforestry systems.

Botanical description

Calathea allouia is a perennial species which forms clusters of 1 m in height. It has ovoid or cylindrical, tuberous roots which ar 2 to 8 cm long and 2 to 4 cm in diameter. The leaves have an enveloping base forming short pseudostems; the petioles are long and striated, the leaf blades elliptical – similar to those of rattan palm – and measure 20 to 60 × 5 to 20 cm. The flowers are white, approximately 2 to 5 cm long, with a staminode and trilocular ovary. Tuberization begins at the end of the fibrous roots.

The tuberous roots contain 13 to 15 percent starch and 6.6 percent proteins (in the dry matter). Of the amino acids (the tryptophan content has not been measured), only cystine deficiency has been noted; this is of no great importance because Guinea arrowroot is not a food in regular use. There are high levels of all the other amino acids, chiefly the essential ones.

In the INPA collection, the plants flower only in some 2 percent of the specimens and do not produce viable seeds. Guinea arrowroot is reproduced vegetatively, through rhizomes, on each side of which about 20 shoots appear.

Ecology and phytogeography

Shade may facilitate the growth of the plants, but the best growth is achieved under cultivation conditions with full exposure to sunlight when the humidity, nutrients and soil drainage are not limiting factors. The cycle from planting to harvesting lasts nine to 14 months, depending on the climatic conditions. Some authors have reported that water shortages can reduce the plant's cycle, causing a reduction in the production of tubers. With introductions from Lábrea and Tefé and with irrigated cultivation beginning in the rainy season, tubers have been harvested after 253 days in Solimões, Brazil.

Guinea arrowroot requires soils of medium texture because very clayey soils impair the development of the tuberous roots while in sandy soils its growth is deficient.

Guinea arrowroot is distributed geographically through Puerto Rico, the Antilles and countries situated in northern South America (the Guyanas, Venezuela, Colombia, Ecuador, Peru and Brazil) – countries in which it is assumed to have originated. There are records of Guinea arrowroot's introduction into India, Sri Lanka, Malaysia, Indonesia and the Philippines.

Genetic diversity

The genus *Calathea* has wide genetic diversity. Over 100 species have been described, chiefly in tropical America. *C. lutea*, a species of the same genus, known as cauassú, casupo, white leaf or bijão, is a tall shrub of the lower region of Amazonia, used to produce wax. Another two species of economic interest from the Marantaceae family are *Ischnosiphon arouma*, known as tiriti, the branches of which are used to make baskets, and *Maranta arundinacea*, known as arrowroot or araruta (in Brazil), whose rhizome yields a starch of high viscosity.

Although it is cultivated only on a small scale by some traditional growers and indigenous pop-

FIGURE 28

Guinea arrowroot (*Calathea allouia*)

ulations, Guinea arrowroot can be found practically throughout the Amazon region. The tuberous roots are usually sold at the open fairs and markets of towns such as Manaus, Belém, Porto Velho, Santarém, Tefé and Benjamin Constant, in Brazil, and in Iquitos in Peruvian Amazonia. There are no bibliographic records on the use of cultivars genetically intended for commercial exploitation. In the last 15 years, INPA has carried out research and distributed reproductive material to small farmers as part of its extension activities. This material comes from collections gathered within Amazonia.

Observations made on the basis of research and collection maintenance programmes suggest the presence of a certain genetic variability among the different introductions, particularly when morphological characteristics and tuber size are examined.

Owing to its status as a crop of limited economic importance, Guinea arrowroot has undergone little research, and bibliographies relating to the species are scant. Genetic resources are maintained practically *in situ* by traditional growers and indigenous populations. Mention should be made of a collection at the USDA's Mayaguez Institute of Tropical Agriculture in Puerto Rico as well as of INPA's efforts aimed at widening the genetic variability of its collection through new introductions.

It may be assumed that, at present, genetic erosion is high. In the last 30 years, traditional growers have gradually abandoned cultivation of Guinea arrowroot.

Cultivation practices

The species is propagated by rhizomes. When the tuberous roots have been harvested, they are stored in a cool, dry place until they are transplanted.

Guinea arrowroot is normally grown in small areas where subsistence farming is frequently carried out in association with cassava, plantain or fruit-trees. In Puerto Rico, it is sown in the shade of coffee trees. Its association with woody species is due to the fact that total or partial shade is necessary for good vegetative development.

After planting, Guinea arrowroot needs little care. In areas infested with phytoparasitic nematodes, Guinea arrowroot shows no symptom of pest attack. It is antagonistic to the gall nematode, *Meloidogyne incognita*, because of its root secretions which impair the larvae's hatching, penetration and reproduction.

The physical and chemical qualities of the soil affect Guinea arrowroot's productivity. Productivity of the tuberous roots is quadrupled if they are grown on plots treated with organic fertilizers (fruit and vegetable waste). The right soil for growing Guinea arrowroot seems to be clayey-loam, which retains nutrients and allows good drainage, although organic matter also needs to be added.

The plants are generally planted with 0.6 m between rows and 0.45 to 0.80 m apart. In research carried out by INPA in Manaus, distances of 1 m between rows and 0.50 m between plants are being adopted. Observations indicate that denser plantings are to be more recommended.

Water supplements are a necessary condition for good yields. Low yields are mainly due to drought at the end of the rainy season. By irrigating the plantation in critical periods, a product yield of close to 15 tonnes per hectare and with more uniform roots has been achieved in Manaus.

The yield from the experimental plantations of INPA in Manaus has been very variable. Productivity per plant is between 100 and 2 200 g. Planting in sandy soil with the addition of organic matter has achieved yields of 936 g per plant. Product yields of 10 tonnes per hectare, and on small plots of 2 to 12 tonnes per hectare, have been reported.

The underground part may be subject to sporadic insect attack. The larvae of coleoptera and lepidoptera cause lesions in the rhizomes and tubers while mite damage has been seen on the leaves and causes the plants to die.

Tuberous roots in clayey soils can be harvested by simply pulling up the plants. However, the most usual way is to hoe the soil carefully around the plant so as to facilitate its removal without damaging the tuberous roots. After harvesting, these may remain for up to ten weeks in open and ventilated environments. In spite of the marked weight loss – 29 percent after ten weeks – the best method of storing the tubers is to put them in the vegetable fibre baskets which farmers use to store roots, tubers and meal, and which are lined on the outside with dry leaves. Storage in special preservation units reduces weight loss, but seriously damages the tuberous roots, impairing the characteristics which are considered to be good for marketing.

Prospects for improvement

Knowledge concerning the genetic improvement of Guinea arrowroot is still incipient. Its commercial exploitation is rare and its cultivation using modern techniques is little developed. In fact, the gradual abandonment of its cultivation by traditional farmers may lead to an extreme reduction in genetic variability and even to extinction of the species.

Basic biological studies that can form the basis for phytotechnical improvements need to be encouraged and new vegetative propagation techniques researched. For example, immersion of the rhizome in hot water at 48°C for ten minutes before planting increases sprouting by 24 percent compared with an untreated control. This experiment shows, furthermore, that too prolonged an immersion also has harmful effects.

Other research shows that the photoperiod has a pronounced influence on the initiation of the tuberization process which is caused by short days, whereas rhizome formation is favoured by long days. Nocturnal temperatures of 10°C reduce the plants' general growth and inhibit tuber formation. In Puerto Rico, it has been noted that, when the rhizomes are planted during the November-December period, no dormancy is exhibited, and tuberization is high with sowing in mid-November and in full sun. Irrigation is an important factor in the productive process and must be constant throughout the plant's cycle. Guinea arrowroot is a species very sensitive to small water shortages and a greater availability of water has the effect of bringing forward and stimulating growth of the tuberous roots and encouraging the formation of new rhizomes.

The evolution of Guinea arrowroot has the exceptional characteristic of being included within the limits of a traditional agriculture or an indigenous agriculture. This aspect of the crop is a challenge to the researcher who must carefully choose the most appropriate direction for the development of the species. What is its place to be in the agriculture of the future? It will undoubtedly depend on the evolution of agriculture itself. It is improbable that its place is in monoculture with an intensive use of inputs and with high yields, and it is probably only a matter of time before it is completely abandoned in that context. The solution for its survival can be found only within the framework of traditional indigenous agriculture. The current renewal of farming activities in fragile and complex environments such as the humid tropics, and more especially those of the Amazon region, represents an effort of synthesis in which science interprets traditional agricultural techniques, reconstructing them at a higher level. However, this new method of management alters the models on which agroforestry was conceived: self-sustainability, the integration in space and time of its component elements, the optimization of the use of available resources and the adaptation of production agents to ecological processes.

Guinea arrowroot is a vegetable that is especially recommended for use in agroforestry systems where its agronomic limitations, considered from the point of view of conventional monoculture (for example its shade requirement and its method of propagation), could be changed into advantages.

Lines of research

Current research projects will have to examine two aspects:

- *Genetic resources:* the collection of germplasm in all distribution areas in America; the establishment of at least two gene banks, one in Central America and the other in northern South America; and the carrying out of origin tests to identify agronomically superior genotypes.
- The development of production plans and research on agroforestry systems.

Production plans must be devised for Guinea arrowroot in order to define the desired biotypes in the genetic improvement programmes.

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Maté
(*Ilex paraguariensis*)

Botanical name: *Ilex paraguariensis* A. St-Hil. var. *paraguariensis*
Family: Aquifoliaceae
Common names. *English:* maté, Brazilian tea, Paraguay tea; *Guarani:* ka'a; *Kaingangue:* kongóñ; *Spanish:* yerba mate, té de los jesuitas; *Portuguese:* congonha, erva maté

Maté, with a very restricted distribution outside America, is a tree that produces a raw material for industrialization and consumption as a stimulating infusion. So far, this has been the main use of this somewhat overlooked crop.

Although no archaeological remains have been found that show that it was used in pre-Columbian times, it is assumed that it was the Guarani Indians who taught the Spanish how to use it. However, what seems to be an indirect consequence of the discovery is the fact that the first people to have cultivated this species were the Jesuit missionaries who, around 1670, already had artificial maté plantations. In time, the settlements of Guarani Indians converted to Christianity were to become economically dependent on maté production.

The expulsion of the Jesuits from the Spanish dominions (1767) was a step backwards in the history of maté. There was a return to the forest exploitation method which utilized the natural maté plantations exclusively and inadequately. It may be said that this type of laborious and uneconomical forest management extended up to the first decades of the twentieth century, in spite of maté planting having been renewed in Nueva Germania, Paraguay and in Santa Ana, Argentina, in 1897.

Although very much reduced, maté production did not disappear with the Jesuit plantations. During the remainder of the colonial period, the use of this herb, which had spread extensively, persisted even in the region of the Viceroyalty of Peru, where there was another methyl xanthine stimulant of the same genus: *Ilex guayusa* Loes. emend. Shemluck, also marketed by the Jesuits from that region in Quito.

It has been established that trade in maté was not interrupted and that it was commonly used in what is now Peru and Ecuador. However, following the independence of the Spanish colonies and the adoption of free trade, English tea began to be introduced into those countries and so maté gradually lost the markets of those Andean countries.

The decline and complete disappearance of the maté plantations in the settlements of Christianized Indians (which ended around 1820 after a series of wars waged in the region between the Spanish and Portuguese Crowns, followed by the struggles for independence) and the policy of isolation and control of international trade maintained by the first governor of independent Paraguay meant that, in the 1820s, Brazil began commercial exploitation of its natural maté plantations.

The most accessible plantations were situated

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in the vicinity of Curitiba, Paraná, and as they were slowly exhausted they were gradually replaced by the others located towards the west. The Brazilian product, which then began to spread on the markets as "Paranaguá maté", was considered to be of inferior quality to that from Paraguay. However, in the course of time it replaced the Paraguayan product, a development which became more marked after the war of the Triple Alliance (1870).

At the end of the nineteenth century, the limitations of the exhaustive exploitation of this forestry resource stimulated efforts to produce large plantations of *I. paraguariensis* once again. Eventually, these efforts were successful, especially in Argentina.

At the same time as the increase in Argentinian maté production, the extraordinary expansion of the agricultural frontiers in traditional maté-growing states of southern Brazil (Paraná, Santa Catarina, Rio Grande do Sul, Mato Grosso do Sul) took place. Regrettably, the disappearance of enormous areas of natural forests in those states jeopardized the conservation of maté's genetic richness.

The complicated economic history of this crop (barely sketched out here) which is characterized by periods of scarcity alternating with periods of excessive demand, the sporadic but real existence of periods during which it was adulterated with other plants and the most common method of preparation – maté sucked through a small tube – considered by many to be unhygienic, had a bearing on the limited spread of maté outside southern South America.

Its main use is in infusions prepared as tea with leaves and dried stems which have been industrially shredded. Generally speaking, it is drunk by filling small gourds (maté gourds or *cuias*) with maté, to which boiling water is gradually added, the liquid being sucked up through a metal tube (the *bombilla*). Infusions of *cimarrón*, or bitter maté, are usually modified with sugar (sweet maté), milk or aromatic herbs. Other methods of consumption are boiled maté, *tereré* (maté prepared with cold water, common in Paraguay and northeastern Argentina), liqueurs prepared with maté, ice-creams, desserts, etc. The industry also produces compound maté (which contains aromatic and/or medicinal herbs), soluble maté and maté teabags.

The aqueous infusion of maté owes its stimulant properties to the caffeine content (between 1 and 2 percent) so that, 60 minutes after consuming maté, an average of 80 to 120 mg of this pseudoalkaloid is consumed. Its nutritional qualities are due to its content of vitamins A, C and B complex and the existence of minerals (P, Ca and Fe).

Argentina, the main producer and consumer, grows around 130 000 ha of maté in the northeast of the country (Misiones and Corrientes), which produce about 140 000 tonnes per year. Brazil is the world's second producer, followed by Paraguay. For the Argentinan province of Misiones, maté cultivation represents an important part of the country's GDP.

Botanical description

The maté is a dioecious evergreen tree which grows up to 18 m in height. The leaves are alternate, coriaceous and obovate with a serrate margin and obtuse apex. The inflorescences are in corymboid fascicles, the male ones in a dichasium with three to 11 flowers, the female ones with one or three flowers. The flowers are small, and simple, number four or five and have a whitish corolla. The fruit is in a nucule; there are four or five single seed pyrenes (propagules).

Maté flowers in the spring (from October to November), has entomophilous pollination (diptera, hymenoptera) and fruits from March to June; dissemination is endozoic (birds). There is a rudimentary embryo in many externally ripe

FIGURE 29

A) Maté (*Ilex paraguariensis*); A1) inflorescence; A2) flower; A3) fruit; A4) gourd and tube for consuming the infusion

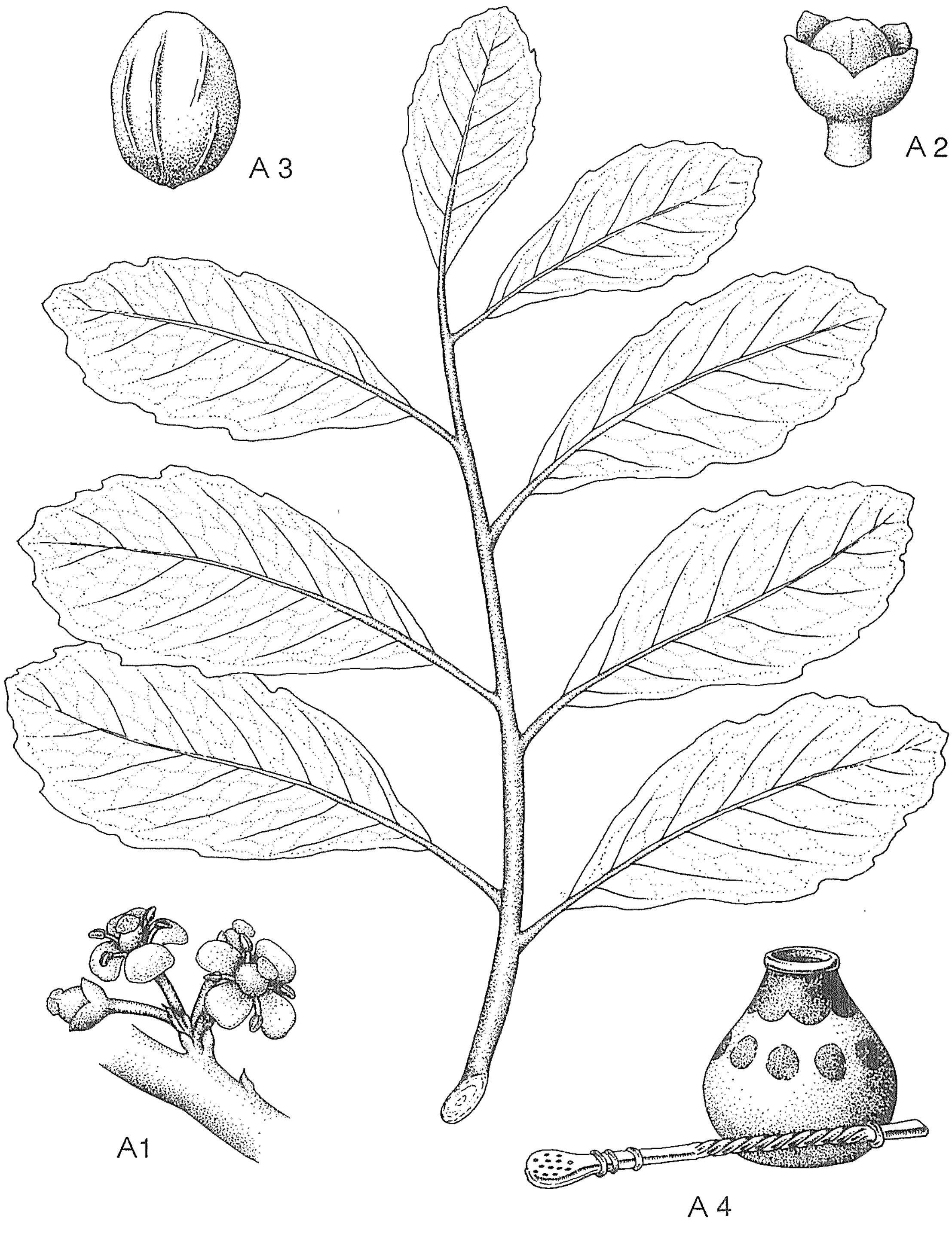
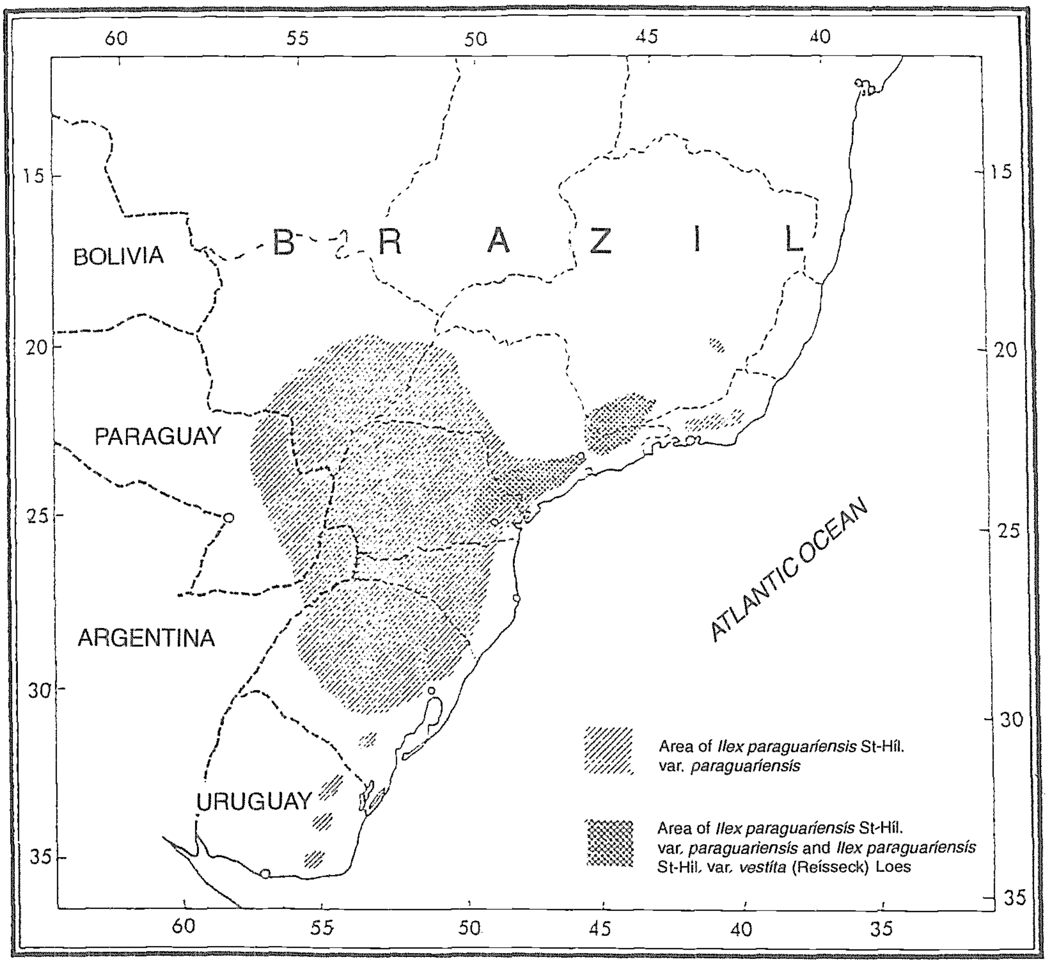


FIGURE 30

Distribution area of *Ilex paraguariensis* var. *paraguariensis* and var. *vestita*



seeds which causes a long period of germination from the time of sowing.

Ecology and phytogeography

Prominent among the ecological requirements of this subtropical species are climatic conditions, especially mean annual precipitation and an even distribution of rainfall throughout the year. This must not be less than 1 200 mm annually and, during the driest quarter – which in the region is winter – the minimum must be 250 mm. *I. paraguariensis*' wild distribution area is always unaffected by water shortages. The mean annual temperature of the area is approximately 21 to 22°C. The absolute minimum temperature that this species is able to tolerate is -6°C, even though winter snows are frequent on the plateaus and mountain regions to the south of Brazil and east of Misiones.

It requires lateritic, acid (pH between 5.8 and 6.8) soils that are of medium to fine texture.

Figure 30 shows the natural distribution of *I. paraguariensis*. The area of economic cultivation of maté coincides approximately with the main dispersion area of the var. *paraguariensis*.

Genetic diversity

There is still no exhaustive modern picture that explains in biological terms the infraspecific variability of this species, which is widely dispersed geographically in South America. Up to the present, taking as a basis the morphological characteristics alone, at least two varieties are recognized: *I. paraguariensis* A. St-Hil. var. *paraguariensis* (cultivated maté, almost completely glabrous) and *I. paraguariensis* var. *vestita* (Reisseck) Loes. (not acceptable for industrialization, of dense pubescence). Both varieties coexist in limited areas of Brazil.

The wild species closest to *I. paraguariensis* belong to the subgenus *euilex* Loes., subsection *repandae* Loes. Only *I. cognata* Reisseck lives in the distribution area of maté. *I. cognata* is very little known; its vernacular name is chá do mato and it is used to adulterate maté.

A number of wild species of *Ilex* are sympatric with genuine maté and have been, or are, used to manufacture the product although, up to the present and according to the legislation in force, they are to be considered adulterations. Of those most frequently referred to, the following deserve mention: *Ilex affinis* Gardner (the ca' a chirí or congonha of Goyaz, a species abundant in central Brazil and northeastern Paraguay); *I. dumosa* Reisseck var. *guaranina* Loes. (*yerba señorita, aperea ka'a, cauna, caá chiri*), native to Paraguay, Argentina and Brazil, the producer of a bitter-tasting maté and supposedly cultivated in Misiones by the Jesuits to produce their famous "caá miní" maté; *I. theezans*, C. Martius ex Reisseck (cauna de folhas largas, ca'a na, congonha), a good substitute for *I. paraguariensis*, found in Paraguay, Argentina and Brazil. *I. brevicuspis* Reisseck, known as cauna or voadeira, like the previous species, is a faithful companion of *I. paraguariensis* in plant communities characteristic of the region – where *Araucaria* is also prominent – but the product obtained from its experimental industrialization is of low quality.

Outside the natural area of distribution and production of maté, in northwestern Argentina and southeastern Bolivia, *Ilex argentina* Lillo, a related species that is known not to accumulate caffeine but theobromine, has been used to prepare maté. It is a tree characteristic of the area of transition between the forests of Myrtaceae and alder (*Alnus* spp.) of the phytogeographical province of the yungas.

***Known cultivars of* I. paraguariensis.** The infraspecific classification of *I. paraguariensis* is still under study. Consequently, the correspondence between the biological varieties and the horticultural varieties of genuine maté is not clear. Following is a list of some of the varieties recognized as such by growers in the three countries: Erva de talo roxo, Erva de talo branco, Erva piriquita (Brazil); Caá verá, Caá manduví, Caá panambi, Caá cuatí, Caá ñú, Caá eté, Caá mi, Caa chacra, Caá-je-he-ni (Paraguay); Yerba colorada, Yerba señorita, Caá miní (Argentina).

INTA in Argentina recently began to distribute seeds of clones and selected clonal progeny which, following comparative trials, demonstrated their superiority.

In wild South American *Ilex* species and in the maté-growing region, the risks of genetic erosion are high because the natural forest is gradually giving way to agroforestry and livestock production, a process accentuated by the relatively low germinating capacity of many species (especially that of maté). As no suitable method has yet been discovered for maintaining the germinating capacity of *I. paraguariensis* for prolonged periods, there are no seed banks of the species. Nevertheless, at the Cerro Azul de Misiones experimental agricultural station in Argentina, a maté clonal garden began to be developed in 1976, complemented by the nursery started in 1986 with *I. paraguariensis* of various origins and with other species of *Ilex*.

Cultivation practices

In the wide and varied economic production area of maté, the practices for the cultivation or exploitation of natural maté vary considerably in their technical aspects, resulting in different yields per hectare.

Three methods of production can be distinguished which are arranged here in increasing order of importance reflecting the use of techniques and their yields:

Extractive exploitation of the natural forest. Here the richness of natural maté plantations is utilized. Harvesting is not mechanized and the pruning system is generally incorrect. This form of production is diffused mainly in Brazil.

Mixed system or system for the enrichment of the natural forest. This consists of increasing the number of natural plantations and reconstituting those that have been lost. In Brazil, where this method is most commonly practised, it is called densifying the maté plantation. Since, generally speaking, this technique is accompanied by others that increase the yield, such as cultivation care and improved pruning methods, the higher production cost is compensated for.

Cultivated maté plantations. This is undoubtedly the best system, and came into general use in Argentina around 1915. In spite of higher costs, the yield per hectare greatly increases. Complemented by measures such as improvement in the layout of plantations (which have evolved from trees planted in quincunxes, with spaced out plants used by Jesuits, to cultivation following contour lines, with a high density per hectare and use of the *corte mesa* pruning and plant management system), with well-timed pruning, cultivation work and harvesting, this system enabled Argentinian production to exceed that of Brazil, in spite of the former being carried out in a very reduced area and even outside the environments most suited for maté. For example, rising from a density of 1 000 to 1 500 plants per hectare (still fairly widespread) to a density of 2 500 or 4 000 plants per hectare, production can increase from around 1 000 to 1 800 kg to 2 100 to 3 300 kg per hectare.

The *corte mesa* system not only increases the yield but is also better suited to mechanical harvesting.

Yields are improved by: planting following contours; the use of natural or introduced cover (rape, legumes, etc.); fertilization (NPK); weed control (mechanical and/or using herbicides); suitable phytosanitary treatments; and rational harvesting. The relevant experiments have been going on for some years but, regrettably, their results have not become generalized. The introduction into cultivation of improved cultivars is much less widespread.

Conventional propagation techniques. *Sexual propagation* ("seeds" = pyrenes). This is the most common reproduction technique. In the case of maté, the advantage of sexual propagation lies in the fact that the variability in descendants may give rise to individuals better suited to different environments (which on other occasions may not be desired).

The seeds are harvested in the region (from February to April). They must be stratified or sown immediately, otherwise they quickly lose their viability.

Stored at 5°C, they maintain a very reduced germinating capacity (1.7 to 6.6 percent) for a further 11 months. The relatively short period of viability together with the low germination rate (immature embryos, phytosanitary problems) have undoubtedly been the cause of the difficulties in its cultivation spreading to other continents in the past.

Agamic reproduction. Grafting, propagation by cuttings and layering are not very widespread. It is relatively difficult to obtain rooted cuttings and this is generally achieved by using young branches from the stools, irrespective of whether plant hormone treatment is used. Additional experiments are necessary if the intention is to increase the rooting percentage.

In vitro cultivation of *I. paraguariensis* is being tried out in Brazil and Argentina by various research groups, with varying results which still do not clearly indicate which are the economically viable techniques for the clonal reproduction of selected individuals.

According to the Under-Secretariat for Agriculture and Livestock, in Argentina in 1988, the average yield of semi-processed maté was 1 220 kg per hectare.

Prospects for improvement

The limitations of cultivation are due to the fact that there is no demand for the product on a macroeconomic scale. The recurrent cycles of surplus supply, low prices, disinvestment in plantations, scarcity of raw materials, high prices – very often linked with international trading terms between producer countries, which result in a greater distortion – have historically acted against a stable supply of the product in terms of quality and quantity. Even worse, they have discouraged the continuation of basic and/or applied research, which cultivation and processing require. The partial or total absence of knowledge concerning maté biology, plant chemistry, dietetics, agronomics and industrialization have made it difficult to adopt international standards which would lay down norms for the quality of the product and improve and guarantee it over time, depending on its distribution to the major international markets for the production of methyl xanthine infusions.

Potential areas for the introduction of this crop are subtropical regions with acid soils and a water supply similar to those of the species' natural area of dispersal.

It has recently been suggested that *Ilex verticillata*, a North American species, could be a source of biodegradable detergents because of its high saponin content. Since research regarding similar subjects is being continued on *I. paraguariensis* and, furthermore, since other related species are studied even less than maté from the chemical point of view, it would be advantageous to go into these aspects more deeply.

Ilex argentina is also a possible caffeine-free maté and is, moreover, remarkable for its richness in liver-protecting phenolics similar to those in artichokes (*Cynara scolymus*).

There are also reports of a range of non-traditional uses for *I. paraguariensis*, for instance as a source of edible oils, furfural and cosmetics.

Finally, the importance of the wild *Ilex* species in genetic improvement of the crop should be mentioned.

Lines of research

- *Botanical:* Infraspecific variability of *I. paraguariensis* and how it is related to other species of the genus; an updated chorology; crossing systems of *I. paraguariensis* and other species of *Ilex*; inheritance of sex.
- Physiology of the seed and micropropagation methods.
- *Plant chemistry:* Cycle of the xanthines in the species and its relatives; toxic and undesirable compounds of allied species; analytical determination of the infusion's flavour components.
- Updating, from the food point of view and with relation to allied species.
- Architecture of the individual of *I. paraguariensis* and of allied species; phenology and adaptation of these trees to mechanical harvesting.
- *Industrialization:* Improvements in the drying and accelerated seasoning systems without organoleptic losses; alternative industries with cultivation by-products.

- New ways of consuming and presenting the product.

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Tannia, yautia (*Xanthosoma sagittifolium*)

Botanical name: *Xanthosoma sagittifolium* (L.) Schott

Family: Araceae

Common names. *English:* tannia, tania; yautia, new cocoyam tanier; *Spanish:* yautía, malanga (Antilles), macal (Mexico [Yucatán]), quiscamote (Honduras), tiquisque (Costa Rica), otó (Panama), okumo (Venezuela), uncucha (Peru), gualuza (Bolivia), malangay (Colombia); *Portuguese:* taioba, mangareto, mangarito, mangarás (Brazil); *French:* chou Caribe (Antilles); *other languages:* queiquexque (Mexico), tannia, taniera (Antilles)

Two Araceae are attaining world importance as energy foods: the cocoyam, taro or dasheen (*Colocasia esculenta*), originating from Oceania and Southeast Asia, and the tannia, yautia or new cocoyam (*Xanthosoma sagittifolium*) from the American tropics. The usable parts in both species are the subterranean tuberous stems which, in the case of the latter, contain between 15 and 39 percent of carbohydrates, 2 to 3 percent of protein and 70 to 77 percent of water; both have a nutritional value comparable to the potato and are probably easier to digest. A secondary use is of consumption of the young leaves, similar to spinach, and this is more common with *X. sagittifolium* than in the case of the taro.

Cultivation of tannia or yautia must be very old in the New World. It may have originated in the northern part of South America and spread through the Antilles and Mesoamerica. When the Europeans arrived it was known from southern Mexico to Bolivia, but was possibly more intensive in the Antilles. Domestication may have occurred in various places and with different materials, and was based on processes such as roasting and cooking the tubers, thereby eliminating the irritant substances, calcium oxalate crystals and saponins.

From America, the tannia or yautia reached West Africa, which is now the major producer. There, it has been displacing the cocoyam or taro because of its better yield and because it can replace yams for preparing *fufu*, a very popular food in tropical Africa.

The tannia has traditionally been a subsistence crop and any produce which is not consumed by producers' families goes to the market. This explains its marginalization because, even though it is a staple for millions of people in the tropics, little information is available on its cultivation and requirements.

This situation is changing with the opening of new areas of consumption, especially on the Atlantic coast of the United States, where millions of Latin Americans consume tannia and other tropical crops, a fact which has promoted commercial production in the Antilles and Cen-

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tral America. This market, which requires high-quality and well-presented products, determines the rules on production and marketing.

As in the case of other neglected crops, there have been very few efforts to industrialize and diversify the product. In Puerto Rico, tests have begun with very satisfactory results for making crisps using instant dehydration and tannia flour. Considering that a very varied industrial production has been built up using tannia, it may be predicted that, with the application of technology, tannia can be used to make a series of industrial products similar to those obtained from the cocoyam or taro.

Production in the family or commercial undertaking must be considered in the context of the production of other energy foods in the same region: cassava, potato, sweet potato and yam. On most of the Latin American markets, the tannia is valued as a superior species because of its flavour and texture.

Surveys carried out in Puerto Rico show that the rural population prefers the tannia to the sweet potato, yam and green plantain because of its flavour and that, in the Philippines, it is preferred to the cocoyam or taro. Production does not meet demand: in Venezuela in 1970, 56 305 tonnes were marketed, a figure which is below potential consumption levels.

Botanical description

A herbaceous perennial, *Xanthosoma sagittifolium* has a corm or main underground stem in the form of a rhizome from which swollen secondary shoots, or cormels, sprout. Several large leaves also sprout from the main stem, which are sagittate and erect with long, ribbed petioles; inflorescences sprout between the leaves in a spadix, with a white 12 to 15 cm spathe which closes at its base in the form of a spherical chamber and opens at the top into a concave lamina; the spadix is cylindrical, slightly longer than the spathe, with female flowers on the lower portion, male flowers on the upper portion and sterile flowers in the middle portion. The spadices are rarely fertile and produce few viable seeds. The growth cycle lasts from nine to 11 months: during the first six months the corms and leaves develop; in the last four months, the foliage remains stable and, when it begins to dry, the plants are ready for the cormels to be harvested.

Ecology and phytogeography

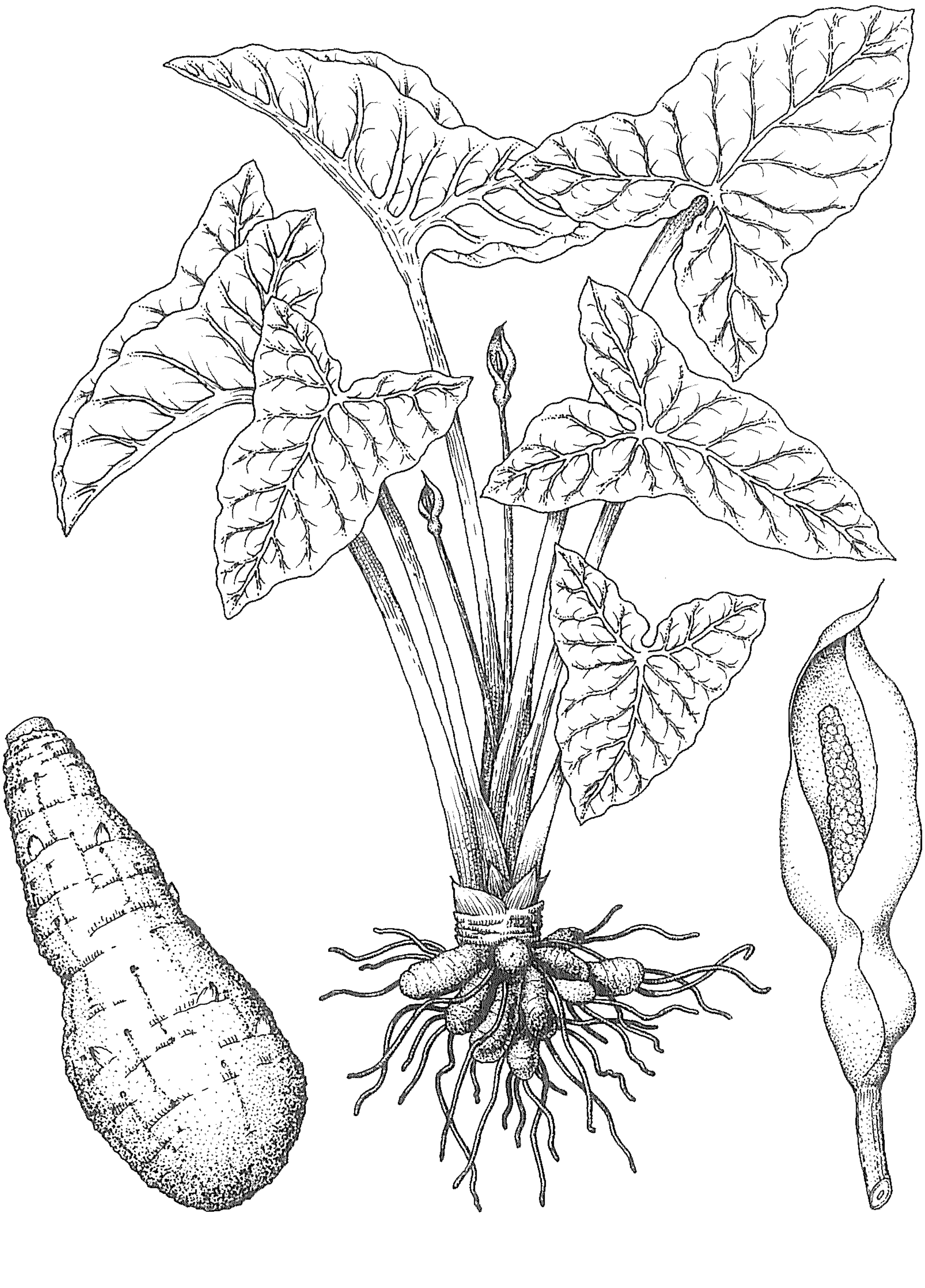
The *Xanthosoma* species are plants of the tropical rain forest and, although in their natural habitat they grow under the forest canopy, under cultivation they are usually sown with full exposure to sunlight. They require well-drained soils and do not tolerate the permanent presence of water. The mean temperature for their optimum growth must exceed 20°C.

Genetic diversity

The taxonomic position of the *Xanthosoma* species cultivated for their underground stems is unclear. The cultivated varieties have been allocated to four species: *X. atrovirens*, *X. caracu*, *X. nigrum* (*X. violaceum*) and *X. sagittifolium*, but some cultivars are not assignable to any of these. Furthermore, the characteristics distinguishing species and cultivars – leaf shape, nervation, petiole colour – are not clearly defined. In one related species, the cocoyam, with a possibly wider variation, all the clones are considered as a single species. In *Xanthosoma* spp. and the cocoyam, the great diversity known (more than 100 clones in the case of the cocoyam) may be due to certain segregations (in the cocoyam and *Xanthosoma* spp. seed formation is very rare) or mutations of the leaf bud. In both cases, growers who detect a new variant maintain its cultivation and reproduce it by vegetative propagation. In recent years, the tendency has been to give the

FIGURE 31

Tannia, yautia or new cocoyam (*Xanthosoma sagittifolium*)



name of *X. sagittifolium*, which applies predominantly to all cultivated clones of *Xanthosoma*, until a modern revision of the genus clarifies the taxonomic situation of the species mentioned.

Xanthosoma cultivars have been described on the basis of collections established in Puerto Rico and Trinidad and Tobago, with indigenous or introduced materials, and do not exceed 50 in number. They display a wide diversity of habit, leaf shape and colour and cormels. As experimental crops show, there are wide variations in yields and the same may be said of the carbohydrate and amino acid content.

There is an urgent need to establish live and *in vitro* collections at world level that enable genetic potential to be evaluated as regards current needs and problems. This means collecting the known cultivars, both in the New World and in Africa, and exploring the northern part of South America in search of possible wild forms and primitive cultivars as well as related species (such as *X. jacquinii*). *In vitro* cultivation now enables healthy and easily transportable propagation material to be obtained. Cytological studies of a world collection may lead, as in the case of the cocoyam, to the establishment of natural groups of cultivars and may also serve as a basis for genetic improvement. The IBPGR recently published a list of descriptors of *Xanthosoma*.

Cultivation practices

Propagation. The planting material most commonly used are portions of the central corm, from 100 to 150 g, with three or four buds. They give greater yields than the cormels which are also sometimes used.

In Costa Rica, a system has been developed for supplying growers with "seed" originating from virus-free cultivations of stem tips grown *in vitro*. With this material, not only is the yield quadrupled but the exportable portion of the harvest increases from 40 to 80 percent, which amply compensates for the cost of sowing. Elimination of the malanga (tannia) virus is so far the most remunerative control operation in tannia cultivation.

The system consists of producing plantlets in public or private laboratories, which supply them to growers or cooperatives capable of developing them under the special conditions required. These plants provide traditional "seed", i.e. portions of stems or whole cormels which are sold to growers as virus-free planting material.

Planting. The ground for planting is ploughed and raked and mounds or ridges are formed for planting the seed. Planting is done in ridges when harvesting is semi-mechanized. The portions of the corm are placed at a depth of 6 to 7 cm since, if planted closer to the surface, they produce numerous side shoots which reduce yield. The planting distance in commercial cultivation is 1.3 m between rows and 40 to 50 cm between plants. In small plantations, they are planted in mounds spaced at 1 × 1 or 1.3 × 1.3 m. In Nigeria, the best results were obtained with distances of 1.6 × 1.6 m on plots where cormels were planted.

Cultivation. The first six months is a critical period for weed control. Backed up by the application of pre-emergence herbicides, preparation of the ground for planting (ploughing and raking) helps considerably in controlling weeds. As the plants need to be earthed up several times, this contributes to keeping the soil clean.

The use of chemical and organic fertilizers is widespread both in small and commercial plantations. In the latter, several dressings of fertilizer are applied; for example, the recommendations in Costa Rica are 150 kg per hectare of 10-30-10 at the time of sowing, 200 kg of Nutrán after two months and 200 kg per hectare of 15-3-30 after four months.

The most serious problem at present is "dry disease", a complex produced by fungi (*Rhizoctonia*, *Phytium*) and bacteria (*Erwinia*, *Pseudomonas*) which attack the young plants, causing leaf wilt and tuber rot and resulting in the complete loss of the harvest. Disease control is difficult and a complete investigation of the problem is therefore needed. For the time being, draining the soil, planting in ridges and crop rotation are recommended.

Harvesting. In commercial plantations, harvesting is carried out ten to 12 months after planting, when the leaves have turned yellow and are beginning to dry. The crop is harvested by hand or by a semi-mechanized method. In the latter case, the tractor has an iron plate as wide as itself attached to it, with a central point which digs into the row of plants, turns them over, and leaves the central stem and cormels free; these are subsequently collected by hand.

The commercial product is washed, dried and disinfected carefully before being placed in boxes in cold-storage rooms.

In small plantations, harvesting of the cormels begins four to six months after planting and is done without uprooting the plant.

Prospects for improvement

Tannia production could be considerably improved, both as a subsistence food and as a product for commercial export and industrial use. As in the case of most neglected crops, no research has yet been carried out on the most elementary aspects, because no new technologies have been disseminated and because of the shortage of marketing systems nationally and internationally.

The role of the tannia in sustainable farming systems must be carefully studied, particularly in mixed plantations. Although under these conditions it is interspersed with taller crops which shade it and reduce its yield, the additional income earned by the grower is very substantial.

The wide genetic diversity must be exploited both directly by the evaluation of cultivars regarding their resistance to disease, yield and nutritional value, and by genetic improvement (which has barely begun). The aim should be to achieve a production of 30 tonnes per hectare with a 10 percent protein content.

The industrial utilization of tannia has only just begun and it may be expected to be as varied as that of the cocoyam or taro, being used in foods prepared for children, flour, crisps, etc.

The main limitations to the development of tannia as a crop are diseases, particularly "dry disease". This problem, which is complex, must receive immediate attention, attacking it from the phytosanitary and agronomic angles.

The tannia, like few neglected crops, is a special case (there is no exchange of information or germplasm between the producing areas) because of the range of its cultivation, which already extends over all tropical regions. When it becomes intensified in a region, the progress recorded does not spread far for geographical or linguistic reasons.

This situation must be corrected by the establishment of a centralized information system such as the cooperatives for tomato, gourd and sorghum cultivation, to which all interested countries and agronomists have access. This may lead to the exchange of germplasm *in vitro*, visits from scientists and farmers who may pass on as yet unpublished experiences and the use of other means of communication which serve to notify progress achieved locally.

The future of the tannia, a food of exceptional value because of its organoleptic characteristics and nutritional properties, lies in a widening of export markets, the application of technology to diversify its use and the promotion of more intensive consumption in people's diets in tropical regions.

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Across the Atlantic: Spain

Processes and causes of marginalization: the introduction of American flora in Spain

A retrospective view of Spanish agriculture and the range of species cultivated during the last 500 years would clearly show the considerable change that has taken place regarding the nature of crops. These changes are evident not only through the gradual incorporation of American flora into the Iberian and island agricultural landscape (potato, maize, sunflower, beans, tomato, American cotton plants, avocados, custard apple, tobacco, etc.), but also through the loss of quite a few cultivated species during the centuries prior to Columbus's voyage. In fact, many species that have been forgotten in agriculture are now being discovered thanks to documentation from the Hispano-Roman period, which can be studied, for example, through Columela (first century); the Hispano-Visigothic period, to which Isidore of Seville refers (seventh century); or better still from the very abundant information passed down by the Andalusian agronomists of the Hispano-Arabic period – Arib Ibn Said (tenth century), Ibn Abi Yawad (tenth and eleventh centuries), Ibn Hayyay (eleventh century), Ibn Bassal (eleventh century), Al Tignari (?), Ibn al-Awamm (twelfth century) and Ibn Luyun (fourteenth century), among others.

We shall take as a reference southern Spanish agriculture of the fifteenth century. This is a subject for which valuable information is available thanks to the Hispano-Arabic authors of past centuries. It was primarily by way of Andalusia that exchanges of samples and seeds with America were to be promoted and carried out during the sixteenth and seventeenth centuries through the centralization of trade, operated by the Casa de Indias in Seville.

Furthermore, it was the land of western Andalusia which the Spanish Crown initially had available for producing the wheat which was to feed the colonies of the New West Indies and make up for the cereal shortages recorded from the earliest times on American soil.

The conquest of western Andalusia by the Christian kings lasted from 150 to 200 years, beginning in the thirteenth century. Consequently, agriculture was to a large extent transformed on the basis of the Castilian model (cereal and livestock). However, in eastern Andalusia the Hispano-Muslims of the Nazari Kingdom had just been vanquished and not only their agricultural landscape and customs but also their own population had remained in the region for some time. Hieronymus Münzer, a traveller from Nuremberg who visited the Iberian peninsula between 1494 and 1495, described the Kingdom of Granada recently conquered by Christian armies and referred in admiring and respectful terms to Nazari agriculture, wich was organized into gardens and irrigated, drawing attention to the excellence of their cultivation techniques, the development of irrigation methods and the wide biodiversity of cultivated species and varieties, established on a notably tree-covered landscape.

The diversity of agricultural species was simi-

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lar to what might have been imagined in the whole Iberian south from the tenth century onwards, until the Castilian feudalism inherited from the Visigoths gradually put an end to the more privatized, kitchen-garden agriculture of the Andalusian period. Through the *Kitab al Filaha*, the agriculture treatise by Ibn al-Awamm – certainly the most important and encyclopaedic of the medieval writings of the European west – the main features of this landscape can be discovered. Arboreal crops dominated by olives, vines, almond trees, carob trees, fig trees, peach trees, apricot trees, apple trees, pear trees, medlar trees, quince trees, chestnut trees, walnut trees, pistachio trees, hawthorn trees, date palms, lemon trees, citron trees, sour orange trees, jujube trees, nettle trees, mulberry trees and hazelnut trees, as well as holm-oak, strawberry-tree and myrtle. Kitchen gardens with lettuces, carrots, radishes, cabbages, cauliflowers, melons, cucumbers, spinach, leeks, onions, aubergines, kidney beans, cardoons, artichokes, purslane and numerous aromatic plants (basil, cress, caraway, saffron, cumin, capers, mustard, marjoram, fennel, melissa, lemon verbena, thyme...).

Fields of cereals and pulses sown with wheat, barley, rice, millet, maize and spelt among the former; and broad beans, kidney beans, peas, chickpeas, lentils, vetch, lupins and fenugreek among the latter. Sugar-cane crops on the coast of Almuñécar and Vélez-Málaga; fibre plants such as flax, cotton (Asian) and hemp; dye plants such as safflower, madder, henna, woad plant and saffron; and tanning plants such as sumac. Wild species such as esparto, osier and oil-palm were used; conchillas and silkworms were reared by cultivating their host plants; numerous ornamental species were planted in gardens and an enormous number of medicinal herbs were used. This was the agricultural landscape before 1492.

If we compare the agriculture of southern Spain under the Catholic kings with the official agriculture in Castilian Spain at the time of Alonso de Herrera (sixteenth century) as well as with that of the Austrians (Gregorio de los Ríos), that of the Enlightenment and Decline of the Empire (Lagasca, Rojas Clemente, Claudio and Esteban Boutelou, Arias and Costa) and that of the first half of the twentieth century (Dantin Cereceda), we can see there has been an obvious loss of a number of crops. We should therefore ask the following questions: Which were the marginalized species? Which were the American species introduced into Spain? How and which way did they arrive? What caused the marginalization of Iberian crops? Was this marginalization a consequence of the spread of the American species? What were the mechanisms of substitution or marginalization?

We shall now endeavour to answer each of these questions.

NEGLECTED SPECIES

Widely different species have lost much of their importance, been marginalized or even completely forgotten. Some remain in the wild state, growing in ditches and on the boundaries of cultivation, as a testimony to their past agricultural use, and they even behave as weeds of other crops. Others have disappeared completely from Spanish agricultural flora. Here they are grouped under different headings according to their utilization.

Horticultural species

This is perhaps the group with the largest number of marginalized species, especially horticultural species which may be called bitter. The species involved are mainly consumed as greens (boiled, cooked in butter or oil or fresh in the form of salads). Some current gastronomies in Europe (and also in America because of the export of the crop and traditional consumption patterns) even use them preferentially as a garnish for meat. There are others which are very flavoursome and which are difficult to separate from their categorization as spices or aromatic plants. These include Amaranthaceae: *Amaranthus lividus* (blite); Apiaceae: *Foeniculum vulgare* (fennel), *Pastinaca sativa* (parsnip), *Smyrnium olusatrum* (alexanders or alisander); Asteraceae: *Taraxacum officinale* (dandelion), *Silybum marianum* (holy, milk thistle or lady's thistle), *Cichorium intybus* (chicory, succory or witloop), *Scolymus maculatus* (spotted golden thistle), *Scolymus hispanicus* (Spanish salsify, golden thistle or Spanish oyster plant), *Tragopogon porrifolius* (salsify or vegetable oyster), *Scorzonera hispanica* (scorzonera or black salsify); Boraginaceae: *Borago officinalis* (borage), *Simphytum officinale* (comfrey); Brassicaceae: *Eruca vesicaria* (rocket, garden or salad rocket), *Nasturtium officinale* (summer or green watercress), *Lepidium sativum* (cress), *Armoracia rusticana* (horse-radish); Polygonaceae: *Rumex acetosa* (sorrel) and other species of the genus; Portulacaceae: *Portulaca oleracea* (purslane); and Chenopodiaceae: *Atriplex hortensis* (orache), *Chenopodium album* (goosefoot or fat-hen).

Many other species may also have been cultivated or perhaps only utilized in their wild form, such as *Silene inflata*, *Campanula rapunculus*, *Salsola* spp., *Chenopodium bonus-henricus*, *Bunias erucago*, *Barbarea verna*, *Cochlearia officinalis*, *Cardamine vulgaris*, *C. pratensis*, *Lepidium campestre*, *Rapistrum rugosum*, *Capsella* spp., *Crambe* spp., *Carduus benedictus*, *Carthamus coerulescens*, *C. arborescens*, *Arctium lappa*, *Reichardia picrioides*, *Calendula officinalis*, *Hyoseris radicata*, *Chrytmum maritimum*, *Eryngium maritimum*, etc.

Legumes

Included here are various grain legumes used as human food, animal feed or both, such as: *Lathyrus sativus* (grass pea, kasari, chickling vetch), *Lathyrus cicera* (vetchling, flat pod pea), *Trigonella foenum-graecum* (fenugreek), *Vicia ervilia* (bitter vetch, lentil vetch), *Vicia monanthos* (one-flowered tare, one-leaved vetch), *Vicia narbonensis* (Narbonne vetch), *Vigna sinensis* (cowpea, blackeye bean, black-eyed pea).

For example, the latter were cultivated on the peninsula before American beans were known (*Phaseolus* spp., chiefly *P. vulgaris*). These would be mainly the species *Vigna sinensis* or perhaps also *Dolichos lablab*, both Phaseolaceae of the Old World known for many centuries in the Mediterranean west, although cultivated especially in the Hispano-Arabic period. To appreciate the neglect or marginalization which these legumes have suffered as a consequence of the introduction of American beans (kidney beans, field beans and also green beans), it will be remembered that, according to the text of Ibn al-Awamm, at least 12 "species" (cultivars) of them were grown in Al-Andalus as a minimum, which bore names such as Marfilada, adivina, jacintina, dura or bermeja, de picaza, alfahareña, romana, etiópica, blanca, etc. This genetic biodiversity was accompanied by a wide diversity in the forms of consumption: as a vegetable (the pods, prepared with oil and vinegar), in soups together with salted fish, as a flour made from the seeds boiled in water, and as a purée prepared from this flour used to accompany other dishes, also seasoned with spices.

This group should also include a substantial proportion of the germplasm of other grain legumes, which are extensively used for human consumption and which today are grown abundantly, but whose infraspecific variability, at local variety or cultivar level, has been considerably reduced during the last few centuries; for example, *Cicer arietinum* (chickpea), *Pisum sativum* (garden pea), *Vicia faba* (broad bean) and *Lens esculenta* (lentil).

Cereals and other grains

We may mention the marginalization of *Panicum miliaceum*, *Setaria italica*, *Pennisetum glaucum* (Pearl millet, African or bulrush millet), spelt (*Triticum spelta*, *T. dicoccon*) and to a lesser extent sorghum (*Sorghum* spp.) among cereals, or the total neglect of other non-gramineous grain species once used as a source of carbohydrates. This is the case with bugloss (*Anchusa officinalis*) or plantain (*Plantago* spp.). Hemp, flax and sesame also figured among the grain species that were known to the agronomists of past centuries.

Fruit-trees

Except for some local and very recent recovery, some species that were once frequently cultivated have now almost completely disappeared from cultivation on the peninsula. These are: *Citrus medica* (citron tree), *Pistacia vera* (pistachio tree), *Ziziphus lotus* (lotus tree), *Sorbus domestica* (service tree or sorb tree), *Crataegus azarolus* (azarole), *Celtis australis* (hackberry or nettle tree) and *Myrtus communis* (myrtle).

Other species, which were perhaps of more importance, are gradually being reduced, put to other uses or grown in a more marginal way, such as *Ficus carica* (part of whose biodiversity has been lost in cultivation), *Cydonia oblonga*, *Ceratonia siliqua*, some citrus fruits such as zamboa or bergamot as well as local varieties of apple, pear, peach, etc.

Aromatic, perfume, dyestuff, colouring and tanning plants

Although some spices and aromatic plants such as saffron have withstood the passing of the centuries, others have lost their importance and have been partially or completely replaced by the introduced American species (*Capsicum* spp., in particular) or as a result of intensification of the international spices market. This is the case, for example, with garden cress and some mustards. Today, certain European and Mediterranean aromatic plants are perhaps cultivated much more or used much more in Latin American cooking than in Spanish cooking (coriander and rosemary, for example). Of the dyestuff plants, the cultivation of plants such as the woad plant (*Isatis tinctoria*), henna (*Lawsonia inermis*), dyer's mignonette (*Reseda lutea*) has been lost and a similar thing has occurred with tanning plants such as sumac (*Rhus coriaria*).

ARRIVAL OF AMERICAN SPECIES

Sixteenth and seventeenth centuries

American species began arriving in Europe with Columbus, thus ushering in an irregular but continuous process in the transfer of germplasm and ethnobotanical information relating to the use of new American crops; this is still going on and is currently even being stepped up. The causes, arrangements and places of arrival as well as the nature of the species brought from America to Spain during the first two centuries of trade are known through the accounts of the same voyages made by Columbus and, later, from the accounts by the chroniclers of the Indies (Fray Bartolomé de las Casas, Gonzalo Fernández de Oviedo, Bernal Díaz del Castillo, Bernardino de Sahagún, Alvar Núñez Cabeza de Vaca, José de Acosta, the Incan Garcilaso de la Vega and Bernabé Cobo), together with the narrations of others who did not cross the Atlantic, such as Francisco López de Gomara, Pedro Mártir de Anglería and Andrés Bernáldez. The work of the doctor and naturalist from Seville, Nicolás Monardes, along with the plant catalogues in various herbaria and botanical gardens of the time such as those of Castore Durante, Jacques Daleachampe, John Gerard, Charles l'Ecluse (Clusius) and James Donn are also basic reference documents. Finally, the enormous mass of information contained in the *Archivo general de Indias* is a monumental source of direct, official information on the transport of all kinds of goods – including plant germplasm – between the New World and Spain. We have consulted a small part of the texts, although the 14 million documents still contain numerous unpublished data on the subject.

In the first decade which followed the arrival of Columbus on the American coast, special arrangements applied to some extent as regards the Spanish Crown's economic/commercial treatment of its new colonies. In the edict issued to govern Columbus's second crossing, there is clear evidence of the attempt to control rigorously the number of people, animals, plants, minerals and objects crossing the sea in either direction. Although this was the initial spirit in 1493, two years later, responding to the expectation which arose as a result of events, the Crown allowed all its subjects to travel to the West Indies to settle, explore or engage in trade, although always under very stringent and certainly onerous conditions. Around 1501, the policy of the Catholic kings changed again, with severer restrictions being imposed on free trade: no one could settle, discover or explore in the new territories without royal approval. To put an end to these waverings, the Casa de Contratación de las Indias was established in 1503, with its headquarters in Seville; over the next two centuries it was to exercise iron control over the traffic of people and goods with America.

In spite of the initial theoretical motives of Columbus's voyage, his descriptions and his admiration for the natural beauty of the islands discovered, and in spite of the fact that some contemporary historians cling to the interpretation that the plant world was also a part of the interests and motivations of the Spanish adventurers of the sixteenth century, we are more inclined to accept the view that the conveyance of plants became a very secondary objective compared with the feverish desire for gold and other metals; Columbus himself was a victim of it during his first voyage.

At the outset, what was the overall attitude of the Europeans towards the vast ethnobotanical culture of the Amerindian peoples and the ancestral agricultural tradition of many of their ethnic groups? Surprise and curiosity, naturally, but also traces of reticence and distrust which were even reflected in contempt for, and the persecution of, some native cultures (the Huautli). From Spain, the main foods and herbs which constituted the diet and official medicine were sent on a massive scale. For example, when in Mexico in 1524, Cortés asked Spain "that each ship should carry a certain number of plants and should not sail without them, because this will be very important for the population and its perpetuation".

During the first decades of the sixteenth century, the sowing of wheat was persistently attempted in the new lands. Juan Garrido and Alonso Martín de Xerez were the first to sow it successfully in New Spain, and Beatriz de Salcedo in Peru. As early as 1531, there were people specializing in this crop on American territories, in spite of the many difficulties that cereal farming encountered among the Indians. In view of the inability of the colonies to become self-sufficient in wheat, it was decided that western Andalusia should become the granary of the New World and that colonists interested in the pursuit of metal should be fed with Andalusian flour. However, Andalusia was not even able to provide for its own needs. Famine raged and periods of high mortality were recorded in Andalusia. Wheat was finally imported from Sicily and Naples into Seville, whence it was taken to America.

During this first half of the sixteenth century, the seeds of many vegetables were also sent. The species most quoted in the documents kept in the *Archivo de Indias* include: cabbage, turnip, radish, borage, bottle gourd, Savoy cabbage, carrot, spinach, aubergine, lettuce, cucumber, cardoon, onions, spring onions, cucumbers, garden cress, melon, purslane and celery. There were also many spices and aromatic plants such as mustard, basil, rosemary, lavender, fennel, rue, coriander, cumin, hempseed, parsley, oregano and aniseed. These attempts at introducing species which would finally end up neglected in the mother country (borage, garden cress, purslane...) seems nothing less than shocking. In 1520, Cortés informed Charles V that, at the market of Tenochtitlán, onions, leeks, garlic, garden cress, borage, sorrel, cardoons and golden thistle were already to be seen. Some of these greens, such as spinach, beet and garden cress, were subsequently to lose their importance but others, such as the cardoon, cabbage, lettuce, radish, broad bean, turnip and carrot, were the vegetables most eaten in Mexico City in 1526.

With this attitude and policy of imposing European agriculture, crops and methods of consumption on America, the process of incorporating local agricultural cultivation, transporting plant species to Spain and assimilating the ethnobotanical knowledge of the indigenous races took place in a climate of indifference, randomness and disorganization. Spain was to prove much more an instrument for extending Europe's influence in the New World than a channel for American plant germplasm to reach the Old Continent. Up to the mid-sixteenth century, plant species reached Europe generally as a result of private initiatives. It was an activity which began with the first voyage of Columbus, transporting potatoes or sweet potatoes (*Ipomoea batatas*) to ensure provisions for his crew during the return journey. From then on, a long succession of plants crossed the Atlantic and were unloaded in Spanish ports, chiefly in Andalusia. There was a gradual flow of maize (*Zea mays*), beans (*Phaseolus vulgaris*), gourds (*Cucurbita* spp.), chili (*Capsicum annuum*), upland cotton-trees (*Gossypium hirsutum*), cassava (*Manihot esculenta*), tobacco (*Nicotiana tabacum* and *N. rustica*), groundnut (*Arachis hypogaea*), maguey (*Agave americana*), pirú or American mastic (*Schinus molle*), pineapple (*Ananas comosus*), Peruvian mastic (*Bursera simaruba*), jalap (*Ipomoea purga*), black sapote (*Diospyros digyna*), sweet gum (*Liquidambar styraciflua*), peachwood (*Haematoxylon brasiletto*), balsam (*Myroxylon balsamum*), sea grape (*Coccoloba uvifera*), *Bumelia persimilis*, star apple (*Chrysophyllum cainito*), Indian cress, nasturtium (*Tropaeolum majus*), cocoa (*Theobroma cacao*), marigold (*Tagetes* spp.), tomato (*Lycopersicon esculentum*), guaiacum (*Guaiacum sanctum*), prickly pear (*Opuntia* spp. and *Nopalea cochenillifera*) and dorstenia (*Dorstenia contrajerva*), etc.

Details of the arrival of many of these plants will probably never be known because of the excessive zeal of the Crown in checking ships' cargoes. For this reason, the ports of Vigo, Corunna, Santander, Lisbon, Gibraltar, Málaga, Sanlúcar de Barrameda and Cadiz were frequently used as an alternative to the port of Seville where unloading was rigorously checked by officials from the Casa de la Contratación. In this way, many goods were not recorded, including many of these plant species which in principle did not seem to have a real commercial value. Hence they were almost always planted and distributed in the fields before being identified by scholars, so that their first botanical or ethnobotanical descriptions on European soil were very much later than their date of arrival on the continent.

The situation changed considerably after the publication in 1574 of *Historia medicinal de las cosas que se traen de nuestras Indias Occidentales* by Nicolás Monardes, a doctor from Seville, who drew attention to the potential of the new medicinal herbs and their cultivation in Spain. His work was distributed widely and was of decisive importance for other, more rigorous and later works such as those of Dodoens, l'Obel and l'Ecluse at the dawn of the seventeenth century. This is how species such as the following came to be described: flor de manita (*Chiranthodendron pentadactylon*), potato (*Solanum tuberosum*), sassafras (*Sassafras albidum*), white cedar or American arbor vitae (*Thuja occidentalis*), sunflower (*Helianthus annuus*), thorn apple, Jimson or Jamestown weed (*Datura stramonium*), physic nut, purging nut or pulza (*Jatropha curcas*), sarsaparilla (*Smilax* spp.), avocado (*Persea americana*), quinoa (*Chenopodium quinoa*), Indian cane (*Canna indica*), copal (*Protium copal* or *Bursera* spp.), annato, arnatto or roucou (*Bixa orellana*), guava (*Psidium guajava*), soapberry tree (*Sapindus saponaria*), soursop (*Annona muricata*) and papaw (*Carica papaya*) etc.

During the seventeenth century this situation persisted while, at the same time, the European upper class developed a certain taste for the exotic, which was to the advantage of the cultivation of many of the species arriving from America as ornamental plants. After these plants had crossed the Atlantic, the reasons for their use were forgotten in their area of origin, and the ethnobotanical information relating to their properties and applications was completely lost – except for a certain percentage of medicinal plants – and, although important species for human consumption were involved, the primary and indeed exclusive use for quite some time in the majority of cases was ornamental. This phenomenon was so widespread that, out of 146 American species known in Europe at the end of the seventeenth century, 44 were used in Spain as ornamental plants, while only one was used as such on the New Continent (*Tigridia pavonia*, the Aztec oceloxochitl or tiger flower). Much earlier, in *Agricultura de jardines* written by Gregorio de los Ríos between 1590 and 1591 and published in 1604, some 200 species used in the gardens of Castile are mentioned and 16 of them are of American origin. These include *Phaseolus vulgaris*, *Capsicum annuum*, *Capsicum frutescens*, *Helianthus annuus*, *Lycopersicon esculentum* and others which, at the time, appeared to be only of interest as ornamental plants.

Eighteenth century: the Enlightenment

The first encounter between the interests of the Crown and those of the enlightened scholars came when the Bourbon dynasty acceded to the throne. These new dynamics, which were absent under the Austrians – except for the feeble support given by Philip II to the Protomedicato of Francisco Hernández – encompassed natural history, and consequently botany, within the eighteenth century conception. This concept recognized the need to obtain more and better information on the planet's biological and geological riches as a means of utilizing them more profitably. There were also reasons of state for reappraising the role of agriculture (which had ranked very low on the social scale since the Catholic kings) and these led to a heightened interest in the introduction of new crops and products into the empire's commercial channels.

This profound change in thinking and political conception began during the reigns of Philip V and Ferdinand VI and reached its height with the reign of Charles III. Under this monarch, not only was academic interest in the plant world encouraged, beginning with the creation of botanical gardens for example, but scientific expeditions to America were even organized under orders to catalogue the biodiversity of the overseas colonies in order to increase both resources and national prestige. Special attention was to be given to medicinal plants and those capable of certain particular uses, as in the case of dyestuff plants. This is how hundreds of different species arrived in Spain in the form of seed, live plants, herbarium specimens, identifiable fragments, etc.

The only objection to this policy which can be pointed out relates to drawbacks inherent in the centralism imposed by the monarchical absolutism of the time. The material was inexorably conveyed first to Madrid, where the Royal Botanical Garden played a prominent role, whence the plants were then distributed centrifugally. The Royal Gardens of Aranjuez were also to play a particularly important role; here, American species such as *Magnolia grandiflora*, *Liriodendron tulipifera*, *Acer saccharum*, *Acer negundo*, *Robinia pseudoacacia*, etc. are known to have prospered in the second half of the eighteenth century. The long period of transportation, together with the harsh winter climate of the Castilian plateau, meant that most specimens ultimately perished. The creation of acclimatization botanical gardens on the coastal periphery of Iberia and the islands (Orotava, Valencia, Sanlúcar de Barrameda, etc.) only partly remedied these difficulties.

Nineteenth century

During this century, the unifying trends of the social, political and scientific attitudes of the Enlightenment were slower. The traditional difficulties affecting the free and rapid propagation of thinking surfaced once again. Almost all natural history research projects were suspended. Spain's relations with America were limited to a continuous process of decolonization of the old territories of the West Indies.

To assess the extent of transfer of American species to Spain, the data provided by the *Memoria sobre los productos de la agricultura española*, compiled for the General Exhibition held in Madrid in 1857, on the "mountain" of Príncipe Pío may be used. The catalogue of products that the organizers considered as having potentially constituted the exhibition lists a total of 640 plant species of economic interest, of which 130 of American origin, which were typical of any place on the Spanish mainland and the Balearic and Canary Islands. They were basically food, industrial and forestry (timber) species. The edible "roots" mentioned included potatoes (from Ciudad Real, Corunna and Toledo), sweet potatoes (from Málaga, Murcia and Valencia) and Jerusalem artichokes (from Madrid). Cereals included maize (from Corunna, Oviedo, Santander, Barcelona, Valencia and Murcia). The section on other flour grains included quinoa (from Valencia and Zaragoza). Among vegetables were gourds (from Murcia and Valencia), peppers and pimentos (from Murcia, Logroño and Madrid), tomatoes (from Murcia), Chile strawberries (from Madrid), tropical pineapples (from Barcelona) and Indian cress (from Madrid). Legumes included beans (specifically quoted as *Phaseolus vulgaris*, from Barcelona, Valencia, Murcia, Oviedo, Avila, Segovia and Madrid) and groundnuts (from Valencia). Fruit-trees included the cherimoya (from Cadiz, Málaga and Valencia), pecan and hickory (from Barcelona, Cadiz, Madrid and Valencia), sea grape (*Coccoloba uvifera*) (from Málaga) and avocado (from Valencia). Among industrial plants, indigo from the Canary Islands was mentioned. The presence of some species now lost and the absence of other American species that are now better known in Spanish agriculture, such as sunflower, upland or hairy cotton (*Gossypium hirsutum*), papaya, babaco, jojoba, etc., may be noted.

Current trends

During and especially towards the end of the twentieth century, we can observe a massive cosmopolitization of genetic resources, resulting not only from the more rapid flow of genes and information (the elimination of natural frontiers, the technological revolution and the intensification of communications) but also from the aggressive economic policies applied in the agricultural sector. Species and varieties are being introduced and replaced at a rapid rate, causing enormous variations in the agricultural landscape, products and forms of consumption. A frantic search for greater productivity has led to the so-called green revolution, a model of agriculture which, to a great extent, has made it necessary to backtrack as regards agricultural policies. The risks of an extreme oversimplification of the genotypes in production have jeopardized the conservation of the planet's agricultural biodiversity and caused an irreversible loss of genes, traditions of use and consumption, resulting in excessive homogenization of the forms of life and survival of humanity. At the end of the century, an effort is now being made to correct these extremes; unfortunately, however, a race to appropriate a new element of power and control – the planet's plant genetic resources – is also beginning.

In recent times, important substitutions have occurred in Spanish agriculture through the invasion of American species and varieties. An example of this is the pine strawberry (*Fragaria* × *ananassa*) replacing the European or wild strawberry (*Fragaria vesca*), which used to grow wild in the deciduous forests of Spain. Cultivation of sunflowers has considerably reduced the olive-growing area. Some models of Mediterranean agriculture have been replaced by distinctly American patterns. For example, on the coast of Granada and Málaga, the agricultural landscape of carobs, figs, vines (for raisins) and olives has given way to avocados, cherimoyas and, more recently, trials have been carried out with papaw and babaco. Horticulture under plastic in that same region, which has almost completely eliminated sugar cane, produces essentially American species: tomatoes, pimientos, gourds, beans and groundnuts. Extra early potatoes and sweet potatoes appear outside at the end of autumn. Even the traditional varieties of vine have had to be grafted on to American rootstock that is resistant to phylloxera. The degree of "Americanization" of Spanish agriculture is clear: the whole of traditional Spanish gastronomy is governed by American plants: the Asturian fabada, potatoes in picón sauce from the Canaries, Rioja peppers, Andalusian gazpacho or the Catalan escalibada, to mention just a few dishes, require the plant genes of the New World.

MODELS AND CAUSES OF MARGINALIZATION

Before drawing up an overall assessment or conclusive opinion on the role of American flora as protagonist in the partial or total displacement of certain crops, we need to recall the origin of the agricultural biodiversity of the pre-Columbian Iberian territories and the historical events for which they provided the setting during the first decades of Spanish colonization in America.

While Spanish settlers imposed a specific model of agriculture in the New World, attempted to introduce European crops and scorned many of the species used by the Amerindian ethnic groups or caused their marginalization, a persecution and marginalization of the Andalusian farming culture also occurred on the Iberian Peninsula. The final capture of the Kingdom of Granada by the Castilian armies of the Catholic kings, the expulsion of the Jews and Moors later, the persecution of the Hispano-Arabic culture – including the burning of libraries – caused a sudden change in the agricultural structure of many of the Iberian territories, especially in the south. Clear evidence of this retrogression may be seen by comparing the richness – the species mentioned, authors referred to and even concepts – of the work of Ibn al-Awamm (Abu Zacaría) with that of Alonso de Herrera, the priest who, more than 350 years after the Sevillian Arab (twelfth century), was commissioned by Cardinal Cisneros to write a treatise on agriculture in the first decade of the sixteenth century, in view of the "absence of treatises on this subject". Only one-third of the species quoted by Ibn al-Awamm are mentioned by Alonso de Herrera. It should be noted in some cases that rather than "neglect" we may talk of "persecution", as in the case of certain bitter or aromatic vegetables in which the puritan citizens of imperial Spain found aphrodisiac, or simply stimulating, effects. This occurred, for example, with rocket (*Eruca sativa*) and even insinuations concerning garlic can be read in the work of Alonso de Herrera.

The repercussions of the introduction of American flora became apparent gradually, at first with a considerable inertia lasting at least one or two centuries, and became evident only in very recent times. Patterns of competition, substitution or marginalization assumed various forms.

Substitution is more or less total between crops of identical or equivalent use, that is to say between species which could be termed ethnovicarious: for example, *Vigna sinensis* replaced by *Phaseolus vulgaris* (kidney bean); *Lagenaria siceraria* (calabash or bottle gourd) replaced by *Cucurbita* spp. (particularly by *Cucurbita pepo*); *Fragaria vesca* (European or wild strawberry) replaced by *Fragaria* × *ananassa* (pine strawberry); *Gossypium herbaceum* (levant cotton) replaced by *Gossypium hirsutum* (upland cotton).

The substitution which took place in a similar way but which resulted in only partial elimination, eventually made the two crops sympatric: this happened with *Olea europaea* (the olive), whose cultivation area was reduced by that of *Helianthus annuus* (sunflower); *Panicum miliaceum*, *Setaria italica*, *Pennisetum glaucum* (pearl, African or bulrush millet) and to a lesser extent *Sorghum* spp., which were replaced by *Zea mays* (maize); and *Juglans regia* (English walnut) replaced by *Juglans nigra* (black walnut) and *Carya illinoensis* (pecan).

In other cases, replacement was not exactly equivalent as regards the yield obtained, even though it involved similar crops. This occurred, for example, with root or tuber species grown in Europe before 1492, such as salsify, parsnip, alexanders or horse-radish, which virtually disappeared in the face of the sweet potato, Jerusalem artichoke and especially the potato – which were incomparably richer and more productive as far as carbohydrates were concerned – and even though other plants of the same group of Andean origin did not manage to become established (maca, oca, ullucu, mashwa, etc.). In this battle, there was one Mediterranean species which fared well: the carrot.

We may also talk of substitution and marginalization among ornamental species: American cypresses *vis-à-vis Cupressus sempervirens*; *Bougainvillea* spp. *vis-à-vis* jasmine, ivy and honeysuckle; hybrids between American and Mediterranean species of the genera *Populus* and *Platanus vis-à-vis* the European poplars; and oriental planes, marigolds and gerbera *vis-à-vis* cineraria and chrysanthemums, etc. The examples in this connection are countless.

There are other cases of more indirect action: chilies partly displaced a series of condiments consisting of cultivated aromatic herbs (garden cress, rocket, horse-radish, rue, coriander and dill) and partly caused a reduction in the consumption of other imported species, such as clove and pepper.

Almost complete substitutions occurred in the agrosystem. This is the case with the dryland arboreal crops on the Mediterranean coast (almond, olive, carob, vine, fig and pistachio) replaced by the American subtropical crops under limited irrigation (avocado and cherimoya) or by cultivation of early crops under plastic with basically American species (tomato, pepper, gourd and bean) alternating with the sweet potato or early potato.

Another form of marginalization, or rather of even more indirect competition, was that caused by the intentional or spontaneous introduction, and subsequent transition to the wild state, of species such as the century plant or agave (*Agave americana*) or the prickly pear. Their use as quickset hedges displaced other local species of trees, bushes and border shrubs, some of which were used as aromatic plants, medicinal plants and as a source of raw material for craftsmanship. Competition even extended to spontaneous flora, endangering the survival of local endemic species (cf. *Opuntia* sp. on the Canary coast). *Nicotiana glauca* also had similar effects in some areas of the Mediterranean coast. We can see that, in other regions of the world, American flora has reached the point where it has almost completely replaced local flora, as in the case of *Psidium cattleianum* and *Syzygium jambos* on the Mascarene archipelago.

To complete this survey of the mechanisms of competition of American flora with Spanish crops, we cannot overlook the competition from herbs introduced into European agricultural systems. Many of these species arrived accidentally and early attempts were made to cultivate a few of them, but they subsequently reverted to the wild state. The most harmful species of American origin in Spanish agriculture are *Amaranthus retroflexus*, *A. albus*, *A. blitoides*, *Conyza canadensis* and *C. bonariensis*. Other locally important species may be *Euphorbia nutans*, *Eclipta prostrata*, *Phytolacca americana*, *Xanthium spinosum*, *Amaranthus cruentus*, *A. hypochondriacus*, *A. muricatus*, *Oxalis latifolia* and *Paspalum paspaloides*.

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Grain legumes for animal feed

Among the grain legumes from the Old World, we may single out two species of the genus *Lathyrus* (*L. sativus* L. and *L. cicera* L.), one species of the genus *Trigonella* (*T. foenum-graecum* L.) and three species of the genus *Vicia* (*V. ervilia* (L). Willd., *V. monanthos* (L). Desf. and *V. narbonensis* L.) on account of their current state of marginalization. In Spanish, *L. sativus* is called by the popular names almorta, gija, muela and tito and in Latin America by the names alverja and chícharo (in Portuguese it is known as chicharo, in English as chickling vetch and in India as khesari). *L. cicera* is known as titarro, almorta de monte, chícharo, galgana and cicércula. *T. foenum-graecum* is known as alhlova and also heno griego or fenogreco (in English, fenugreek). *V. ervilia* corresponds to the yeros, also known as alcarceña, alverja, alcarraceña, ervilla, lenteja bastarda, etc. (in Portuguese, ervilha de pombo and gero, and in English bitter vetch). *V. monanthos* is the name of algarroba, garroba and lenteja de Aragón (in English, one-flowered or one-leaved vetch, and in Portuguese ervilhaca parda). Finally, *V. narbonensis* is known as alverjón and haba loca (in Portuguese ervilhaca de Narbona, and in English Narbonne vetch).

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This species, along with the garden pea (*Pisum sativum* L.), broad bean (*Vicia faba* L.) and chickpea (*Cicer arietinum*) were the first cultivated legumes, according to archaeological findings of the neolithic period, Bronze Age and Iron Age in Europe, the Near East and the Nile Valley.

Their location has demonstrated the spread of these species from their centre of domestication. Because of their larger size, the seeds that have been found are considered to be cultivated rather than wild forms.

Columela, in *De re rustica* (first century), mentions *Trigonella foenum-graecum* (fenugreek), *Vicia ervilia* (bitter vetch) and *Lathyrus cicera* (vetchling or flat pod pea), referring to their use, soil requirements, tillage and sowing dates. He refers specifically to *L. cicera* as it is cultivated in what is today Andalusia for feeding oxen as a replacement for *V. ervilia* – in the form of milled grains, moistened with water and mixed with straw – also stating that it is not an unpleasant food for humans. *Libro de agricultura* by Abu Zacaría (twelfth century) also mentions *T. foenum-graecum* and *V. ervilia*, referring to their soil requirements, methods and dates of sowing, fertilization and types of use in animal feeding as well as describing their use as a human medicine and other uses. In *Agricultura general*, by Alonso de Herrera (1513), *V. ervilia* and *L. sativus* are also mentioned, with different cultivation techniques and methods of use for feeding livestock and treating ailments recommended. *L. sativus* is used in the human diet in a similar way to chickpeas and is mixed with other grains to make bread.

Table 10 sets out the origin and distribution of the wild or cultivated form of the various species. Because of their marginal character, there are no data on a worldwide basis relating to the cultivated area of this group of legumes. Chickling vetch (*L. sativus*) is widely grown in India, with an area of 1.6 million ha referred to by Duke (1981). Vetchling (*L. cicera*) is currently grown only in Spain, although it was formerly grown throughout southwestern Europe. Fenugreek (*T. foenum-graecum*) is cultivated in the Mediterranean region, the Near East, Ethiopia, India and southern California. In North Africa, it has been grown for fodder around the Saharan oases from very early times. Bitter vetch (*V. ervilia*) is grown in Asiatic Turkey, central and northern Spain and other countries of the Mediterranean region and western United States; the seed is exported to the United Kingdom and other countries for feed, especially for sheep. There are barely any references to one-leaved vetch (*V. monanthos*) or Narbonne vetch (*V. narbonensis*), in spite of the fact that both species, particularly the former, were widely cultivated in the Mediterranean in past times. Figure 34 shows the regressive pattern of cultivation of these legumes in Spain; some of them are practically on the verge of extinction.

COMPOSITION AND USE

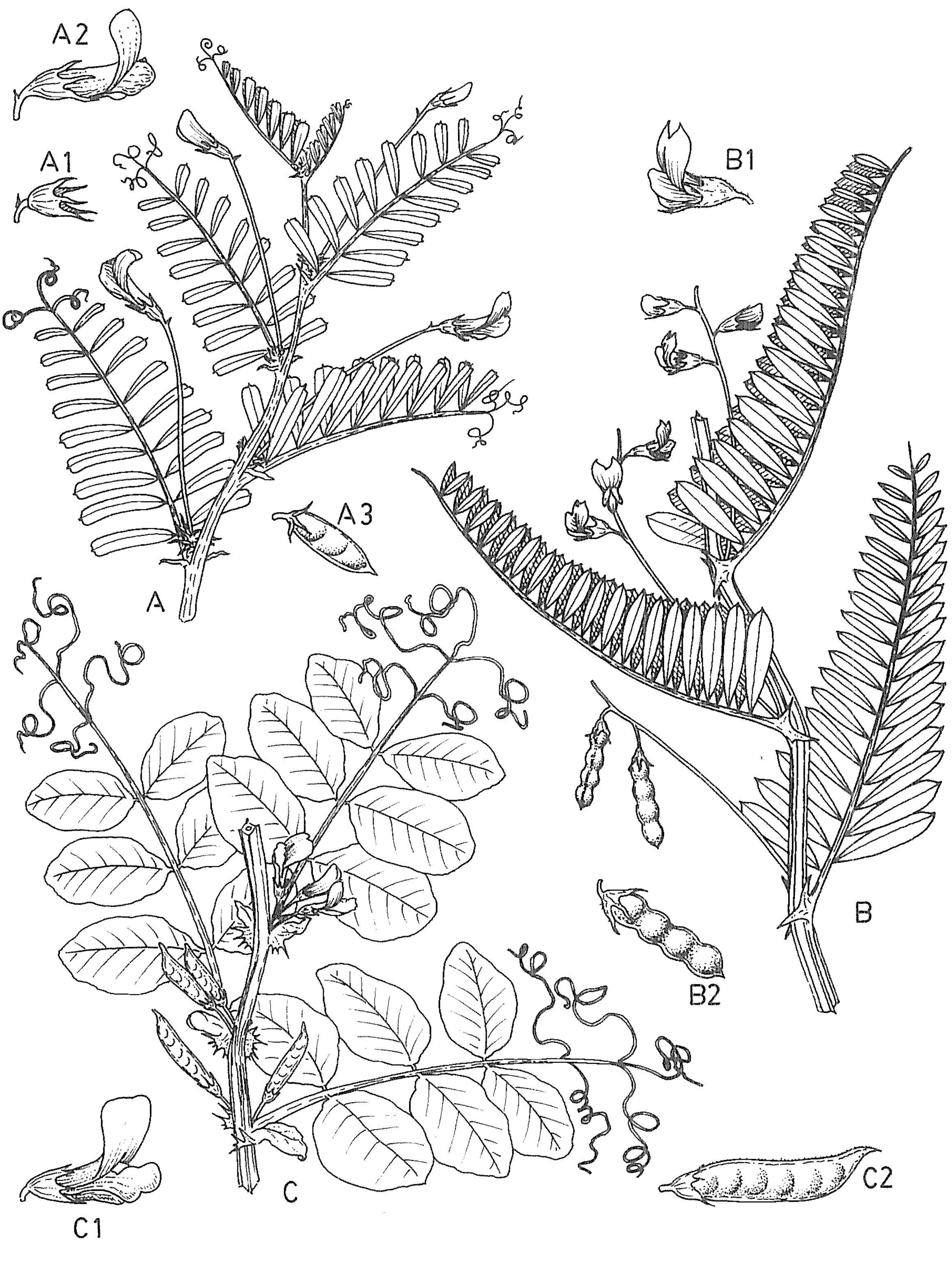
Table 11 sets out the seed composition of the species studied. Protein content ranges between 20 and 30 percent and the fat content is generally very low except in the case of fenugreek (*T. foenum-graecum*). As in the other legumes, lysine is the most favourable amino acid and methionine is the most limiting. Several antinutritional properties are also present in the grain (Table 12). Chickling vetch and vetchling (*L. sativus* and *L. cicera*) contain a neurotoxic amino acid called ODAP (ß-N-oxalyl-L-α-ß-diaminopropionic acid) which causes neurolathyrism in humans and animals. This disease causes paralysis of the lower joints through neurological lesions brought about by degeneration of the spinal cord, particularly in equine stock, if the seed is eaten continually for months as the main component of the diet. In extreme cases it even causes death. Occasional consumption is not harmful and does not appear to affect sheep, so stockfarmers use these legumes for gestating females, fattening lambs and serving males. Macerating or soaking the seed in water, followed by cooking and treatment at high temperatures, seems to inactivate the lathyrogenic component, preventing its toxicity. Chickling vetch (*L. sativus*), which has a white flower and seeds, has a lower ODAP content. In some localities of northern Spain, selected white chickling vetch is traditionally eaten because of its lower content of lathyrogenic substances. There is a negative correlation between the total protein content of the *Lathyrus* and its ODAP content, which is of interest for improving varieties. The ODAP content of chickling vetch grown in Spain is lower than that of Asiatic chickling vetch. It has also been shown that the ODAP content of *L. cicera* is lower than that of *L. sativus* (0.146 and 0.205 percent, respectively).

Fenugreek (*T. foenum-graecum*) has a high content of gums and mucilages (around 28 percent) which makes its direct use in the diet of monogastric species difficult. It contains other substances which give the plant an unpleasant smell, which permeates all its surroundings and is conveyed to the meat and milk of animals that eat it.

The antinutritional factors of the species of the genus *Vicia*, in addition to affecting the nutritional value of the grain, can cause pathological changes of varying extent in animals that consume them, especially birds.

FIGURE 32

Grain legumes: A) one-leaved vetch (*Vicia monanthos*); A1) calyx; A2) flower; A3) legume; B) bitter vetch (*V. ervilia*); B1) flower; B2) legume; C) Narbonne vetch (*V. narbonensis*); C1) flower; C2) legume



The seed is the part mainly used in this group of legumes, although they are also grown as green fodder or hay and play an important role as a green manure, which is dug in at the end of the winter to improve soil fertility. The straw of these legumes is of high nutritional value for livestock.

Among the entire group, it is chickling vetch (*L. sativus*) which is most used for human consumption, in the form of green vegetables; the dry seed especially is soaked in water and boiled or else husked and made into flour for mixing with cereals and making bread or porridges. The latter method of preparation is usual in India (for *dhal*), and it was a popular recipe during times of scarcity and famine in the Spanish regions of Castilla-La Mancha and Extremadura, where many serious cases of neurolathyrism occurred as a result of it being consumed in the wrong way in the 1940s. The current Spanish Food Code prohibits human consumption of chickling vetch seed and the products obtained from its preparation. Mixtures with oilseed cake are used for sheep although, in Spain, its use in animal nutrition is not very widespread because of the fear of lathyrism.

Vetchling (*L. cicera*) is used as both a fodder plant and grain producer. The name *comuña* is given to the mixture of cereal grains, legume grains or both (as well as to their combined cultivation) which provides a complete food for livestock. Its etymological origin is from "*común*" in its meaning of mixture, referring to the mix of seeds obtained when cleaning the grain and which contaminate the main grain, generally wheat. The combination, which was of very variable content, was first formed from spontaneous plants which the farmer improved by introducing other species with a higher yield or quality. In the Spanish region of Tierra de Campos, vetchling began to dominate in *comuña* as a consequence of mechanical selection, since its grain was bigger than that of the vetches and tares, the two names used nowadays without distinction. There is therefore an ancestral knowledge of the use of *comuña* and its lathyrogenic side-effects. The use of *L. cicera* for sheep does not pose any lathyrism problems if doses do not exceed 50 percent of the ration in concentrates.

Fenugreek (*T. foenum-graecum*) is primarily grown for the production of its seed. Its strong smell somewhat discourages livestock from eating it. It must be used in low doses, since it imparts an unpleasant flavour to meat and milk and also causes animals to put on weight, which is not suitable for draught animals. Livestock dealers sometimes use it to tone animals up and give them a transient good appearance. It is also grown as a condiment, an essential oil being extracted for flavouring different foods and drinks, such as cheeses, sweetmeats, pickles and liqueurs. It is also used in the pharmaceutical and cosmetics industry because of the vast range of chemical products that it contains. The plant also has insecticidal properties and is used in stored grains as a repellent. Popular medicine attributes tonic and vermifugal properties to its seeds, the mucilaginous components being used to treat stomach ailments. In Hindu medicine, the seed extract is used because of its cardiotonic, diuretic, antiphlogistic, hypoglucemic and antihypertensive properties. It has active ingredients which act on the metabolism of fats and cause weight loss in women. In India, consumption of the seed is believed to stimulate lactation.

The species of the genus *Vicia* are traditionally used for feeding ruminants, particularly sheep, but they are practically unused for monogastric species in view of the seed's toxicity and its negative effect on growth. Bitter vetch (*V. ervilia*) must not exceed 25 percent of the ration in sheep and cattle feed. One-leaved vetch (*V. monanthos*) is more readily eaten by sheep, but refused by other types of livestock because

FIGURE 33

Grain legumes: A) chickling vetch (*Lathyrus sativus*); A1) flower; A2) legume; B) vetchling (*Lathyrus cicera*); B1) legume; C) fenugreek (*Trigonella foenum-graecum*); C1) flower; C2) legume

of its slightly bitter taste. Birds, with the exception of pigeons, do not take to it. The seed of *V. narbonensis* can be used as feed for cattle which accept it more readily than pigs and sheep, provided it is fed to them in ground form. Like common vetch (*V. sativa*), it has a slightly bitter taste which animals grow accustomed to, but which can be passed on into milk.

BOTANY AND ECOLOGY

Table 13 describes the main botanical characteristics of the various leguminous species studied. Because of their origin, distribution and cultivation, they are suited to Mediterranean ecological conditions. Their cycle takes place in the autumn to spring period and they are resistant to cold and frosts as well as drought, especially in the final phase of cultivation. They are suited to poor soils and frequently to marginal ones (Table 10).

GENETIC DIVERSITY

There is very little information on the genetic diversity, infraspecific variability and relations of these species with other related wild species. Few cultivars are known or well defined. Only limited areas of cultivation remain in some areas of the world and, in many of them, the individuals are threatened. The material available in gene banks is scarce. Consequently, there is the risk that important plant material obtained over thousands of years of cultivation might disappear, while only a few isolated works on classification and selection are to be found.

In the species *Lathyrus sativus*, there are a great number of varieties and types which differ in flower colour, form of growth and colour and shape of the seeds. Two varieties can be distinguished: lesser white chickling vetch and greater white chickling vetch. The first is possibly the original form of the species. Greater white chickling vetch is perhaps a selection of the former, featuring bigger seeds, a lighter colour and a more flattened shape. In India, 56 types have been identified. As in almost all this species group, the types sown are heterogeneous populations of botanical varieties. The centres of diversity are central Asia and the Mediterranean.

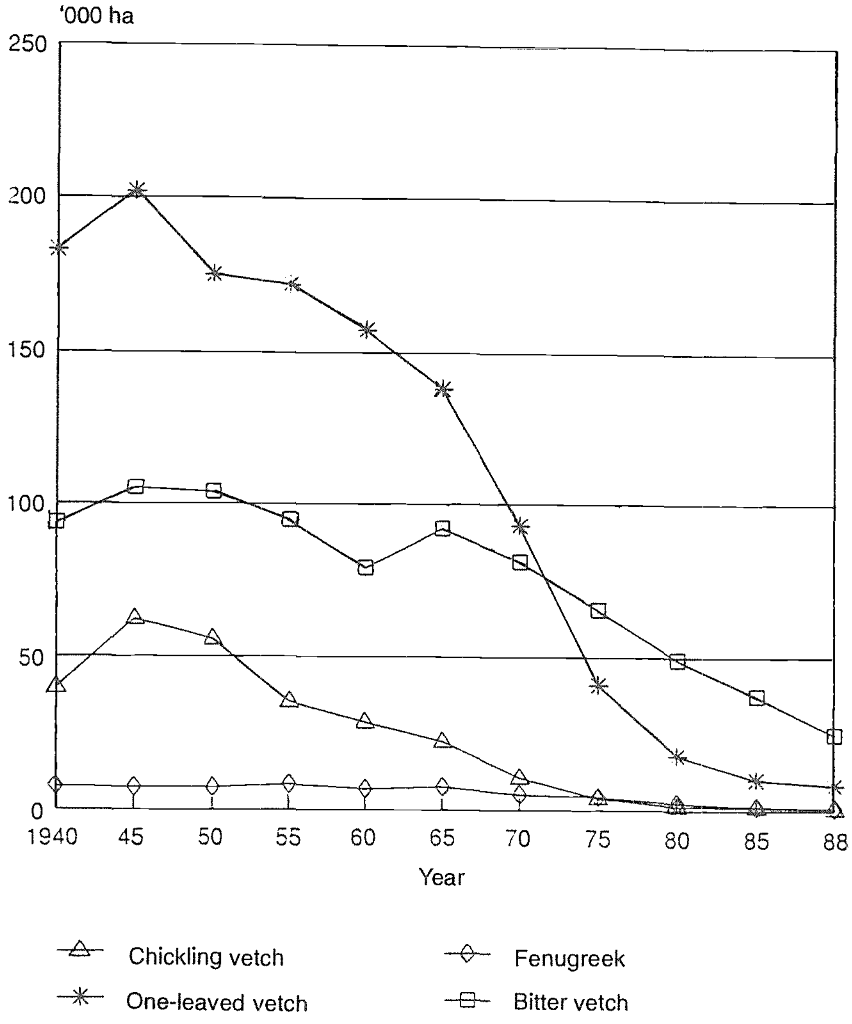
L. cicera is considered to be a semi-domesticated plant, with local varieties and spontaneous plants existing in Spanish cultivation regions, especially in the centre and north. There are local, primitive indigenous varieties in Castilla-León made up of very heterogeneous and widely varying material suited to adverse conditions. This material has traditionally been cultivated in combination with other plants (*comuña*) and its domestication has been rare, in spite of the fact that the plant has been grown for thousands of years. The main changes introduced in these varieties are: a more erect and compact habit of the plant, lesser dehiscence of pods and greater seed size. The wild populations of *L. cicera*, which are abundant in Spain, have characteristics very close to those of the cultivated plants. Domestication of *L. cicera* occurred in southern France and Spain when cultivation of chickling vetch (*L. sativus*) spread to those countries from its area of origin and domestication, which it subsequently replaced. Descriptors have been proposed for *L. cicera* and three botanical varieties are recognized: *pedunculatus*, *foliolatus* and *palentinus*.

Improvement programmes have been designed for fenugreek (*T. foenum-graecum*) to increase the yield of diosgenin, a steroid which is present in the seed and which is used in medicine, as well as to study the behaviour of a spontaneous mutant with earlier flowering and bigger sized seed. Twenty-nine different ecotypes have been recognized. The centre of diversity of fenugreek is situated in the western Mediterranean and the Near East.

The cultivated types and varieties of bitter

FIGURE 34

Changes in the cultivated area of legume species for animal feed in Spain



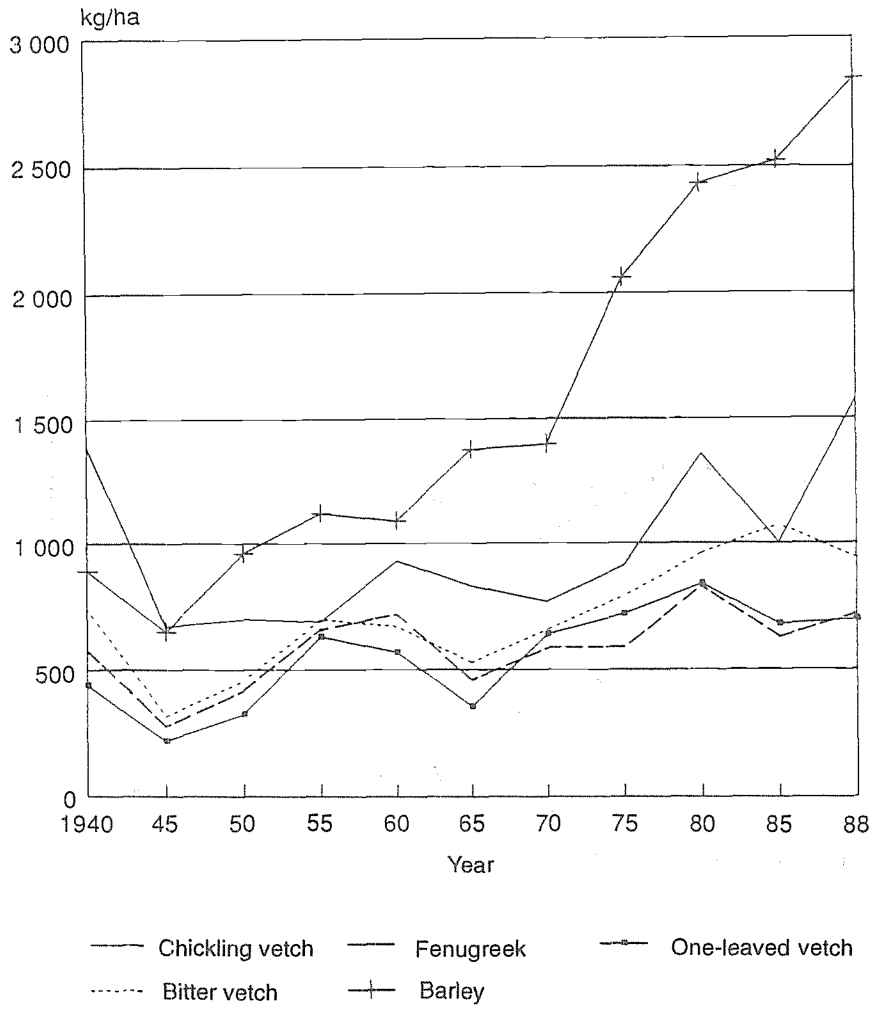
vetch (*V. ervilia*) are very heterogeneous populations which frequently appear mixed with other cultivated or spontaneous species of *Vicia*. In Spain, the variety most used is common red bitter vetch but, in recent years, four selected varieties have been recorded. Comparative tests between these varieties and local controls, carried out in central Spain, have demonstrated the higher yield of the selected material. The centre of diversity of the bitter vetches is situated in the western Mediterranean and in the Near East.

Also in the case of one-leaved vetch (*V. monanthos*), the cultivated varieties are botanically very heterogeneous populations from which selections, lines and ecotypes adaptable to different environments could be obtained. In Spain, two types of one-leaved vetch can be distinguished: the white seed type and the black seed type, depending on the different shades of the background colours of the seed, the black type being grown in a greater proportion and the white type more rarely. The western Mediterranean, the Near East and the Euro-Siberian regions are quoted as centres of diversity.

Vicia narbonensis is considered to be a species very close to *Vicia faba*. It was once even thought that this was the original form of broad bean, although cytogenetic studies showed that

FIGURE 35

Changes in the grain yield of legume species for animal feed grown in Spain



this theory was without foundation. It is thought that the var. *serratifolia* is the origin of the current forms of *V. narbonensis*. Since ancient times, attempts have been made to cross *V. faba* and *V. narbonensis* to obtain an interspecific hybrid that combines the valuable characteristics of both species. In recent years, these crossings have been possible through genetic manipulation and through the embryo recovery technique, enabling valuable material to be obtained when using the appropriate genotypes as parents. Compared with *V. faba*, *V. narbonensis* has a high level of resistance to aphids (*Aphis fabae*), with intraspecific variations for resistance, hence it shows good agronomic potential. It also seems to have greater resistance to broomrape (*Orobanche* spp.), which is why farmers have grown it in the past.

Table 14 sets out the existing collections of germplasm of the legume species studied, according to the country and institution which keeps them. Probably the most complete collection is to be found in Spain. According to the most recent data, there are 49 lines of *L. sativus* from Spain and Portugal; 92 lines of *L. cicera* from Spain; 177 lines of *V. ervilia* from Spain and Portugal; 76 lines of *V. monanthos* from Spain; and ten lines of *V. narbonensis*.

TABLE 10 Origin, distribution of cultivation and ecology of grain legumes

Species	Origin	Distribution	Climate	Soils
Lathyrus sativus L. (2n=14)	Mediterranean, central Asia	Central, southern and eastern Europe, India, Iran, South America	Suited to dry climates, although tolerates an excess of rain. Annual precipitation: 320-1 360 mm. Annual mean temperature: 13°C	Suited to poor soils, it tolerates heavy, clayey soils. Sensitive to acid soils
Lathyrus cicera L. (2n=14)	Mediterranean, western Asia	Southern and eastern Europe, Near East, North Africa	Tolerates cold and frosts in the Mediterranean region, with autumn sowing; resistant to drought in the spring	Suited to poor soils, not too damp or saturated. Prefers heavy, well-limed soils with alkaline pH
Trigonella foenum-graecum L. (2n=16)	Mediterranean, Near East	Southern Europe, North Africa, Near East, India, Ethiopia, United States	Suited to regions with moderate or light precipitation. Development favourable during the cool, temperate growth season. In a Mediterranean climate, with mild winters, it is sown in winter and ripens in spring. Annual precipitation: 380-1 530 mm. Annual mean temperature: 16°C	Grows well on drained, deep, loamy soils and on gravel and sandy soils. Ill-suited to clayey, acid soils. It is damaged by excessive soil dampness
Vicia ervilia (L.) Willd. (2n=14)	Mediterranean, Near East	Mediterranean, Turkey, United States	Very resistant to cold during the growing period because of its sparse habit and branching and slow growth. Very resistant to drought, even in spring. A harvest is obtained even during excessively dry years. In favourable conditions, high yields are obtained. Annual precipitation: 360-1 160 mm. Annual mean temperature: 14°C	Suited to neutral or lightly acid soils. Tolerates limy types of soil, provided they are not too clayey
Vicia monanthos (L.) Desf. (2n=14)	Mediterranean	Mediterranean	Very resistant to low temperatures during vegetative development and to prolonged drought. Suitable crop for regions with late, dry autumns. Sensitive to drought during the flowering period, which reduces the yield drastically. Annual precipitation: 350- 1 230 mm. Annual mean temperature: 11°C	Suited to a wide range of soils provided they are not too damp. Prefers soils that are not very clayey, that are deep and contain little lime. This is one of the legumes which requires the least soil fertility
Vicia narbonensis L. (2n=14)	Mediterranean	Central Europe Mediterranean, Near East, Ethiopia, central Asia, India	Temperature requirement greater than the broad bean (*Vicia faba*) and lesser humidity requirements. Replaces this species advantageously in warm dry areas. It does not tolerate cold, and is damaged by frost	The most suitable soils are loose and sandy, deep and with a good lime content. Tolerates clayey soils that are not too damp

Sources: Duke, 1981; Mateo Box, 1960; Pascual, 1978; Villax, 1963.

TABLE 11 Composition of grain legume seeds

Species	Proteins	Amino acids		Fat	Total carbohydrates	Fibre	Ash
		Lysine	Methionine				
	(Percentage of weight)						
Lathyrus sativus L.	25 - 28	1.84 - 2.47	0.1 - 0.15	0.6 - 1.9	55 - 61	4 - 15	3
Lathyrus cicera L.	25 - 27	–	–	1 - 1.3	56	6	3
Trigonella foenum-graecum L.	23 - 30	1.48 - 2.3	0.35	6 - 8	55	8 - 10	3.6 - 4.3
Vicia ervilia (L.) Willd.	17 - 21	1.53 - 2.02	0.37	1.3 - 2	61 - 64	4 - 6	2.4 - 3
Vicia monanthos (L.) Desf.	22	1.29	0.25	1.6	60	4.8	3.3
Vicia narbonensis L.	23 - 25	1.44 - 1.76	0.11 - 0.18	1 - 1.5	53	7.5 - 10	2.7 - 2.9

Sources: Duke, 1981; Franco Jubete, 1989; Gómez Cabrera, 1983; Mateo Box, 1960; Villax. 1963.

CULTIVATION PRACTICES

The cultivation techniques of these legumes are very rudimentary, given their marginal character, the small yields obtained and the little benefit which they bring the grower. Soil preparation is reduced and no type of fertilization is applied, as sowing is carried out in autumn or at the beginning of winter. Nor is any type of herbicide applied. Harvesting is sometimes done manually and threshing is carried out on the threshing floor, although it is frequently done with a motorized reaper, followed by threshing and cleaning and, less often, with a combine harvester.

Table 15 sets out the traditional cultivation techniques for each species. Some tests on new cultivation techniques have been carried out in Spain recently. For *L. cicera* in addition to a better selection of seed, it has been proposed that 125 kg of seed per hectare be used and herbicides applied (propyzamide + diuron or trifluralin + linuron), while harvesting should be done by reaping and leaving the crop in rows to ripen, or else using a modified cereal harvester. For bitter vetch (*V. ervilia*) which, among these species, has the biggest cultivated area in Spain and of which selected varieties exist, the use of herbicides (alachlore + linuron, metholachlore + promethrin, cynazine or metazole) is recommended, as is harvesting with a cereal harvester during the first hours of the morning and harvesting only in one direction to avoid the problem of grain loss.

Table 16 shows the grain yields of each species in different regions and countries, both in normal cultivation conditions and in trials.

PROSPECTS FOR IMPROVEMENT

Since the appearance of modern agriculture, biological, technical and economic limitations have caused the present marginalization of these cultivated legumes, the situation of which varies according to the geographical area. Of the countries of the Mediterranean basin, particular reference will be made here to Spain.

TABLE 12 **Antinutritional factors of grain legumes**

Species	Antinutritional factors	Remarks
Lathyrus sativus L.	ß-N-oxalyl-L-α-ß-diaminopropionic acid (ODAP), trypsin inhibitors, hydrocyanic acid, maltose, saponins, quercitin, flavins	Neurolathyrism
Lathyrus cicera L.	ODAP	Neurolathyrism (content less than *L. sativus*)
Trigonella foenum-graecum L.	Complex polysaccharides (gums and mucilages), trypsin inhibitors, sapogenins	Contains numerous chemical components of interest to the pharmaceutical, food, perfume and cosmetics industries (diosgenin, mucilages, coumarin, lecithin, etc.)
Vicia ervilia (L.) Willd.	Cyanogenic glucoside, canavanine, trypsin inhibitors	
Vicia monanthos (L.) Desf.	Cyanogenic glucoside, canavanine	
Vicia narbonensis L.	Cyanogenic glucoside	

Sources: Arora, 1983; Harborne, Boulter and Turner, 1971; Gómez Cabrera, 1983; Mateo Box, 1960; Villax, 1963.

The biological limitations lie in the absence of genetic improvement in a plant material that is extremely diverse and has been cultivated for thousands of years, which is evident from the stability of yields during the last 50 years (Figure 35), depending on the ecological conditions (the differences in the trend of barley yield during the same period can be seen).

The presence of toxic elements or antinutritional factors, the elimination or reduction of which would have to be tackled in breeding programmes, is a restriction on its use in human consumption and particularly in animal feed. Although the list of pests and diseases that attack this group of legumes is very extensive, there are important gaps owing to the low extent of its cultivation and the paucity of studies carried out. However, generally speaking, attack by pathogens is not found to be a serious limitation on cultivation.

Fenugreek (*T. foenum-graecum*) has been found to be tolerant to insects and diseases, chickling vetch (*L. sativus*) to rust and viruses, and *V. narbonensis* to *Aphis fabae*. Among the pests and diseases of economic importance are *Aphis craccivora* and *Myzus persicae* for fenugreek and *Ascochyta pisi* and *A. orobi* for the chickling vetches in India. In Spain, the major pests are aphids (not specified) in fenugreek and one-leaved vetch; *Bruchus* spp. in *V. ervilia*, *L. sativus* and *L. cicera*; and *Apion* spp. in *L. sativus* and *L. cicera*. The major diseases are rusts (*Uromyces pisi* or *U. fabae*) in one-leaved vetch, and nematodes (unspecified) in *V. ervilia*.

From the agronomic point of view, the precariousness of the techniques used has prevented yields from increasing. The use of such techniques is unavoidable because of the lack of response of cultivation to new practices and the low profitability of their application. The difficulty of mechanizing harvesting, given the aerial structure of the plant and its propensity to shedding its grain on ripening, is undoubtedly the factor of greatest importance. Also, competi-

TABLE 13 **Botanical characteristics of grain legumes**

Species	Structure of the plant	Flowers	Pods	Seeds
Lathyrus sativus L.	Branched. Stems suberect and climbing. Height: 40-90 cm. Main root: 50-70 cm. Secondary roots very numerous	Solitary, axillar with a long peduncle. Colour bluish-purple, pink or white	2.5-5 cm long, wide and flattened. Contain 1-5 seeds	Wedge-shaped. Cream or greyish brown, sometimes dark speckled and with a small hilum on the wider edge
Lathyrus cicera L.	Smaller than *L. sativus*. Height: 30-50 cm. Deep taproot (80-120 cm) and fewer secondary roots	Solitary, reddish colour	Typically grooved with 3-5 seeds	Similar to those of *L. sativus*, but less angular and more rounded. Greyish colour with dark spots. 17 000-18 000 grains/kg
Trigonella foenum-graecum L.	Stems erect. Height: up to 40-80 cm. Branched only if there is a high planting density. The plant and seeds have a characteristic strong odour	Solitary or in pairs, axillar and sessile. Colour yellowish white, stained violet at the base of the corolla	7.5-15 cm long, erect and sometimes curved. Longitudinal veins with a long point (2-4 cm). Contain 10-20 seeds	Oblong, quadrangular, sometimes compressed. Yellow or light-chestnut colour. Approximately 50 000 grains/kg
Vicia ervilia (L.) Willd.	Low height (20-70 cm) and little branching. Very trailing habit. Highly developed root system	Inflorescence with 1-3 pendulous flowers joined at the axis by a small pedicel. Whitish colour sometimes with a violet tinge	2-3 cm. Seeds are prominent as the valves adhere to them closely. 2-4 seeds per pod	Tetrahedral, sometimes angular. Light colour, from cream to reddish brown. 25 000-35 000 grains/kg
Vicia monanthos (L.) Desf.	Trailing stems, polygonal in cross-section. Height: up to 80 cm. Deep, very branched roots	Uniflorous inflorescence, with pedicellate, pendulous flowers. Whitish colour	Flattened, from 3-4 cm long. Light-brown colour. 2-5 seeds per pod	Similar to the lentil but smaller and less flattened. Colour variable, from light, pinkish yellow to dark chestnut, with black dots. 10 000-20 000 grains/kg
Vicia narbonensis L.	Stems erect and branched, of quadrangular cross-section. Height: up to 70-80 cm. Deep, well-developed roots	Inflorescence with large violet or reddish flowers and different contours in the various parts of the corolla	5-7 cm long, wide, ending in a short, curved point. Almost black in colour. 6-7 seeds	Spherical with dents, 4 000-5 000 grains/kg

Sources: Duke, 1981; Mateo Box, 1960; Villax, 1963.

TABLE 14 **Collections of grain legume germplasm**

Country	Species	Institution
Afghanistan	*Vicia ervilia*	Plant Research and Soil Science Department, Ministry of Agriculture, Kabul
Australia	*Lathyrus sativus*	Department of Agriculture, Adelaide, South Australia
Bulgaria	*Vicia ervilia*	Institute of Plant Introduction and Genetic Resources, Sadovo
CIS	*Lathyrus* spp.	N.I. Vavilov All-Union Institute of Plant Industry, St Petersburg
Cyprus	*Vicia ervilia*	Agricultural Research Institute, Ministry of Agriculture and Natural Resources, Nicosia
Czechoslovakia	*Lathyrus* spp.	Plant Breeding Research Institute of Technical Crops and Legumes, Tumenice
Germany	*Vicia ervilia* *Vicia narbonensis* *Lathyrus spp.*	Institut für Pflanzenbau und Pflanzenzüchtung, Braunschweig; Zentralinstitut für Genetik und Kulturpflanzenforschung, Gatersleben
Ethiopia	*Trigonella foenum-graecum*	Plant Genetic Resources Center, Agriculture Research Institute, Addis Ababa
France	*Vicia narbonensis*	Station d'amélioration des plantes, INRA, Dijon
Iran	*Trigonella foenum-graecum*	Seed and Plant Improvement Institute; Plant Genetic Resources Division, Karaj
Pakistan	*Lathyrus* spp.	Agricultural Research Council, Islamabad
Portugal	*Vicia ervilia*	Estação Agronómica Nacional, INIA, Oeiras
Spain	*Lathyrus cicera* *Lathyrus sativus* *Vicia ervilia* *Vicia monanthos* *Vicia narbonensis* *Vicia ervilia*	Centro de Conservación de Recursos Fitogenéticos, Ministry of Agriculture, Fisheries and Food, Madrid Estación Experimental del Aula Dei, CSIC, Zaragoza
Turkey	*Lathyrus* spp.	Aegean Agricultural Research Institute, Menmen, Izmir

Source: Esquinas, 1983.

tion from wheat has been a limiting factor on yields when suitable herbicides have not been used. For these reasons, there has been an increase in cereal monoculture and in the area of fallow, while new crops have been introduced on fallow land, for example sunflower, which has been extensively promoted by the extractive industry through the spread of techniques, machinery loans, the granting of advances to farmers and guaranteed purchases. Moreover, changes in irrigation have given rise to the introduction of much more profitable crops such as beetroot and maize.

Traditionally, there has not been a policy for the protection of these legumes (whereas there has been for cereals), nor any marketing channels; there have been shortages in regulation of the supply and the producer sector has been separated from the feedstuffs industry. The latter has been developed under the protection of measures that have favoured soya meal: low-price imports and all types of facilities and aid to producers. As an example, in its common organization of the market, the EEC has recently only provided for aid in the case of fenugreek production, completely disregarding the rest of this legume group.

Within the framework of a sustainable agri-

TABLE 15 **Traditional cultivation techniques of grain legumes**[1]

Species	Tillage	Fertilization	Sowing	Herbicides	Harvesting
Lathyrus sativus L. and *L. cicera* L.	First tillage (sometimes with cultivator or harrow)	None (sometimes 100-200 kg/ha of 18% superphosphate)	In autumn, after the first rains: 150-200 kg/ha of seed (sometimes barley is used as a support at 15-20 kg/ha). With cereal drill, 15-40 cm between rows	None (*Avena* sp., *Papaver* sp. and crucifers)	With cereal harvester (losses 20-30% because of dehiscence and plant's low habit). Also cut with a motor scythe (in rows, dried) and harvester with pick-up
Trigonella foenum-graecum L.	Harrowing and rolling	None (sometimes 100-150 kg of 18% superphosphate)	In October: 110-130 kg/ha of seed. With cereal drill, 15-18 cm between rows	None (*Avena* sp., *Papaver* sp. and *Veronica* sp.)	With cereal harvester (difficulties from flattening and grain drop)
Vicia ervilia (L.) Willd.	Harrowing and/or cultivator and rolling	None (exceptionally 100 kg/ha of 18% superphosphate)	In October-December: 100-130 kg/ha of seed. With cereal drill, 15-20 cm between rows, sometimes broadcast	None (*Avena* sp., *Lolium* sp., *Papaver* sp., *Cirsium* sp., *Veronica* sp., *Poligonum* sp. and crucifers). Very sensitive to hormonal herbicides of cereals which cause serious damage	With cereal harvester and motor scythe, threshing and cleaning. Sometimes manual, with threshing on floor
Vicia monanthos (L.) Desf.	Tilling, harrowing and rolling	None	In October-December: 95-100 kg/ha of seed. With cereal drill, 15-20 cm between rows	None (*Avena* sp., *Lolium* sp., *Papaver* sp., *Matricaria* sp. and *Cirsium* sp.)	Motor scythe, threshing and cleaning. Sometimes pulled up by hand, with threshing on floor

Note: There are no data on *Vicia narbonensis*, as its cultivation is practically non-existent in Spain.

TABLE 16 Grain yield of various legumes

Species	Region	Remarks	Authors
(kg/ha)			
Lathyrus sativus L.			
500 -2 600	Spain	Cultivation	Guerrero & López Bellido, 1983
1 000 -1 500	–	Cultivation	Duke, 1981
312	India	Cultivation	Duke, 1981
2 126 -6 242	Northern Spain	Trials	Franco Jubete, 1989
Lathyrus cicera L.			
1 500 -2 500	Southern Europe	Cultivation	Villax, 1963
1 580 -3 037	Northern Spain	Trials	Franco Jubete, 1989
Trigonella foenum-graecum L.			
750 -3 800	Spain	Cultivation	Guerrero & López Bellido, 1983
500 -3 320	–	Trials	Duke, 1981
3 700	Great Britain	Trials	Duke, 1981
1 000	Morocco	Trials	Duke, 1981
800 -1 500	Western Mediterranean basin	Cultivation	Villax, 1963
338 -1 490	Northern Spain	Trials	Franco Jubete, 1989
Vicia ervilia L.			
400 -2 200	Spain	Cultivation	Guerrero & López Bellido, 1983
1 000 -2 500	Western Mediterranean basin	Cultivation	Villax, 1963
1 299 -2 830	Northern Spain	Trials	Various
2 600 -3 000	Central Spain	Trials	Various
1 580 -2 358	Northern Spain	Trials	Franco Jubete, 1989
Vicia monanthos L.			
400 -1 800	Spain	Cultivation	Guerrero & López Bellido, 1983
106 - 249	Northern Spain	Trials	Franco Jubete, 1989
Vicia narbonensis L.			
1 070 -3 307	Northern Spain	Trials	Franco Jubete, 1989

culture and the Common Agricultural Policy that seeks to encourage alternative crops, the several million hectares of fallow land in Spain could benefit from promotion of the cultivation of these legumes, which are sources of protein and which improve soil fertility. The role of the legumes in soil conservation and environmental improvement should not be forgotten, nor should their non-food uses, such as the production of pharmaceuticals and cosmetics in the case of fenugreek.

In addition, thorough research needs to be carried out in the short and medium term to provide a knowledge and evaluation of the plant material and its genetic improvement, as well as to develop more suitable cultivation techniques for increasing production. Such techniques would then be passed on to farmers, encouraging the cultivation of the different species according to the different cultivation systems and regions. The animal feedstuffs industry must take part in this process, gradually integrating the utilization of these raw materials into their processes.

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Traditional varieties of grain legumes for human consumption

Since the beginning of agriculture, grain legumes have had multiple uses depending on how the different parts of the plant were utilized. The seeds are used dry or green, the legumes green and the plant dry as straw for animal feed and green as fodder or as organic manure. The dried grain is used for animal feed or human consumption. In the latter case, it is used whole or hulled, as flour, boiled or roasted. The flour is used on its own or mixed with other flours, generally made from cereals. Legumes are served as a main dish, either alone or accompanying meat or fish, as a snack, green or dried.

The same diversity exists in the cultivation systems (extensive dry or irrigated, purely horticultural and winter or spring) and in postharvest handling (for fresh consumption, dry storage or immediate use). Packaging can be simple and the product can be frozen or canned or precooked. Grain legumes are a source of oil with which protein-rich cake is made and they also have other substances of interest for industry and pharmacology.

In addition to everything that the plant offers immediately, legumes have constantly been accompanied by species that produce carbohydrates, i.e. cereals in temperate zones or roots and tubers in tropical zones. This is due not only to their great nutritional value, but also to their ability to fix atmospheric nitrogen which is then released into the soil, a fact which has been perceived intuitively by farmers throughout the ages because of its effects on crops and one which necessitated the inclusion of legumes in all farming.

There is always a legume which is suitable for sowing whatever the climate and soil conditions. For example, the cowpea (*Vigna unguiculata*) can be used if the climate is semi-arid and subtropical, which means it can be recommended for cultivation throughout the Mediterranean basin, as indeed happened in the past (until American beans became totally established). The field bean and, in general, American beans (*Phaseolus vulgaris*, *P. lunatus*, *P. coccineus* and perhaps others) share Mediterranean gardens with the cowpea, replacing it in colder regions such as northern Spain. Broad beans do not tolerate subtropical and semi-arid climates but they can be cultivated exclusively to below 400 mm of winter precipitations. They therefore replace cowpeas and beans perfectly in those environments, and even enable new land to be colonized. Below 400 mm, the preference is for the chickpea which, with the broad bean, shares a dual use in food for both humans and animals. Below 300 mm and at a lower temperature, the lentil is the only legume suitable for human consumption that is free from problems (there are restrictions on the consumption of other grain legumes by humans). The garden pea can occupy very different areas: from kitchen gardens, where it is found with the broad bean and haricot bean, up to cold and semi-arid moorland, although it does not tolerate extreme conditions like the lentil.

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It is therefore not surprising that grain legumes have had a favoured position in agriculture and in the human diet. However, according to the overall figures, their situation in world agriculture is currently that of a group of crops clearly in regression. These data are subject to qualification: in fact, horticultural crops are prospering but this is not the case with extensive crops and those specific to subsistence farming. Given that the latter occupy a much bigger area than the former, which in actual fact are concentrated in a few species, the figures may reflect the average situation well but they do not describe it adequately.

This situation affects all species of grain legumes. It should be noted that their decline is occurring in agricultures that make abundant use of technology, i.e. Western or surplus agriculture, in contrast to the subsistence farming of many developing countries. In the latter type of agriculture, legumes may not play a very important role as regards quantities produced, but their value is high from the qualitative point of view, as they generally supply the scarce proteins available for human consumption.

Highly sophisticated agriculture is very recent in humankind's history and is actually a consequence of the industrial revolution of the eighteenth century. At that time in the United Kingdom, scientific principles were successfully applied to certain agricultural problems. Experimentation, at the same time as inventions in other areas of knowledge, caused a genuine agricultural revolution which may be summarized as follows: the demonstration of the fact that monoculture, particularly of cereals, is possible; the gradual introduction of natural or artificial fertilizers; the idea that animals are not essential to farming; the accompanying reduction in the importance of crops intended for animal feeding; the increase in trade by rail or steamboat, which made self-sufficient farming unnecessary; the replacement of oxen and horses as draught animals, with a consequent reduction in the importance of crops intended for them; the production, outside farming, of concentrated or compound feedstuffs; and the abandonment of rural areas, which may still be seen nowadays, in favour of industrial regions.

New scientific improvement was established on a firm basis in the mid-nineteenth century, and the essential needs for crops of the first order were met, in particular, when genetic improvement came into its own this century. Grain legumes were not among them, unless they had a horticultural use, in which case they became part of a refined human diet as a complement and not as a basic food. The legumes of the poor, which had served as a source of protein for thousands of years and which still perform this function through subsistence farming in developing countries, were relegated to marginal regions away from trade routes and scientific interest and away from new agricultural techniques and improvement work.

In an agriculture as highly competitive as ours, while knowing the advantages these species possess as regards a given aspect of farming, farmers put them in second place solely on the grounds of yield. This is reflected in a limited and fragmented supply that is inappropriate for proper marketing and which, in its turn, results in the species' abandonment. It is interesting to note how, in an emergency situation, farmers revert to legumes. In regions of Spain where broomrape (*Orobanche* sp.) has practically caused sunflower to be abandoned, broad beans are once again beginning to be sown. The same can be said of chickpeas in Seville, owing to problems connected to the price of cereals. When agronomy and genetic improvement are applied to legumes, the latter respond generously.

In sum, the situation of the species dealt with here applies also to numerous other legumes: valued by the farmer, the consumer and by industry, their cultivation is nevertheless decreasing from year to year. The ultimate cause of their marginalization is that they arrived late in the marketing world.

COWPEA
(*Vigna unguiculata*)

Origin of the name

Cowpeas today are usually called "caupíes" in Spanish, which is a phonetic transcription of the English name to distinguish them from the cultivated species of *Phaseolus*. However, the Spanish "frijol" or "judía" always corresponded to the vegetable that is now called "caupí" and to a few other species that are related from the agronomic and cultivation point of view (particularly those belonging to the genera *Dolichos* and *Lablab*). The cowpea is the Greek *faseol*, the Latin *faseolus* and the Arabic *fasulia*. It has also been given the name "habichuela", probably because of its pods which are like those of the broad bean for human consumption but finer (the Mozarabic word *favichiela* is found in writings of the year 1100), and the name "judihuela". The latter name, which is important because it is where the word "judía" comes from, and not the other way round, is not easy to define etymologically. It seems that "judihuela" is formed from *faseol* through the Mozarabic *faseol* (*'fusiol*, *'fusiola* which diphthongizes into *'fusihuela*; *'f* indicates aspiration, still present in the old Romance dialects and languages), from which "judihuela" came to be formed through popular deformation and perhaps also through attraction.

Transfer of the name to the species of *Phaseolus* was due to morphological, agronomic and culinary similarity (as well as botanical similarity: delimitation of the genera *Vigna* and *Phaseolus* has not been easy and may still be unsatisfactory) between the old bean and the current bean. In practice, the confusion began with the discovery: Columbus called a bean what obviously could not be so, because of its great similarity with the legumes he knew by that name in Spain. Thus, the superimposition with "caupí" and "frijol" occurred not only in agronomic contexts but also in botany and in the conceptual sphere.

Present situation

The cowpea was still cultivated in Córdoba 20 years ago. It may still survive in some kitchen gardens of the Spanish east coast and in others on the peninsula, but it must be considered to have practically disappeared in Spain. In the supermarkets of the larger towns, it has not been seen for some years: the influence of American salads has even meant that a product is being imported that could be cultivated perfectly well domestically.

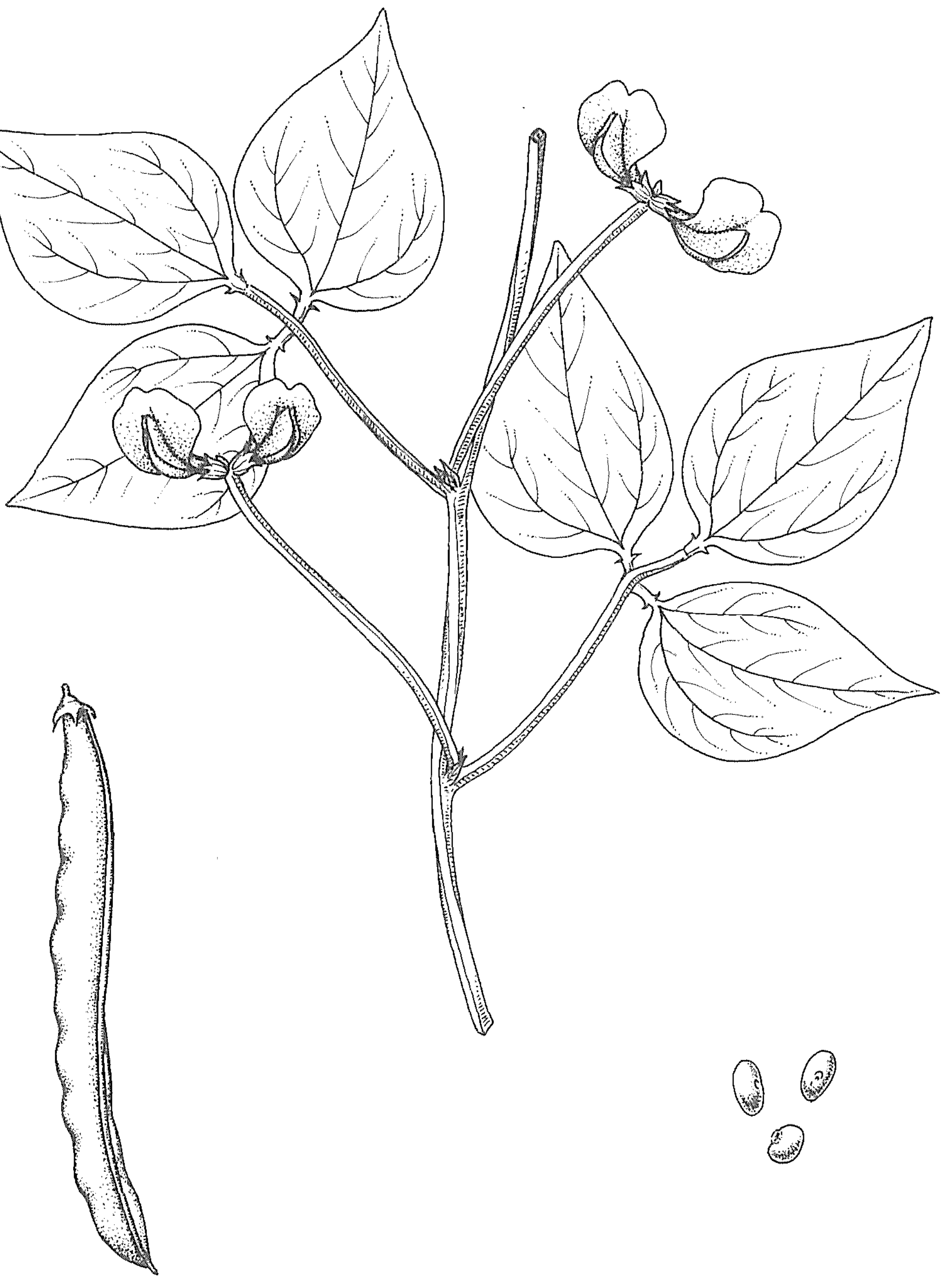
In the collections of grain legumes made on the peninsula, no sample of cowpea was gathered and, if it has been, it should appear among the current beans, pending a botanical revision to classify it correctly. The specific cause of its marginalization, apart from the general causes mentioned previously, is its total replacement by the American beans. Both in the cultivation system and in use (green pod, dry or green seed), the beans of the new continent, and especially *P. vulgaris*, quickly gained an advantage over the cowpea and, around the eighteenth century, it is possible that references to beans under their various names referred exclusively to the latter.

Prospects

The cowpea is one of the priority crops for the IITA, a member of CGIAR, because of its importance in the tropics. The IITA is carrying out extensive work on the cowpea, both in the agronomic and the genetic area, and its future is safe at world level.

FIGURE 36

Cowpea (*Vigna unguiculata*), legume and seeds



As far as Spain is concerned, however, the situation does not seem very promising, unless new culinary uses originating from tropical countries are introduced, and even this will not be enough to re-establish the cowpea significantly in Iberian agriculture.

FIELD BEAN, KIDNEY BEAN, GARDEN BEAN, HARICOT BEAN, FRENCH BEAN (*Phaseolus vulgaris*)

Origin of the name

These names (in Spanish judía, frijol, alubia and habichuela) and others are given nowadays to the species of *Phaseolus* that reached Spain after the discovery, in particular *P. vulgaris*, which is rightly called judía común (common bean). The word "judía" did not appear before the eighteenth century (for example, in Suárez' 1733 edition of the work by Laguna: in Laguna's text, only the word "judihuela" appears, whereas in the comments of Suárez, judía is already synonymous with beans, frisoles, alubias, etc., as well as judihuelas). In some regions, the dried seed is also given the name "chícharo", a term applied to more than one grain legume and obviously derived from the Latin "cicer" which, strictly speaking, corresponds to the chickpea.

Present situation

As already mentioned, the only important species is the common bean. Another two species, *Phaseolus lunatus* and *P. coccineus* are cultivated on small areas for specific purposes (as an ingredient of paella, for example), and the trend is to replace both of them completely with the former. In fact, in the collections of genetic material made in recent years, very few samples of either have appeared and always with some doubt as to whether they are from recent populations or, as would be desirable, old populations. All are summer-grown species in Spain and, consequently, require water. This is why, like the cowpea, they are kitchen garden or extensive irrigation crops, except when dry-farmed in the moist soils of the Cantabrian coast.

The selling prices on the common bean market, both in the pod and fresh, as well as the popularity of some dishes (*fabada*, with chorizo sausage, *pochas*, *caparrones*, green beans, etc.) suggest a promising future for the legume. Although this is relatively certain for the species, it is not so much the case with traditional cultivars. One has only to compare the situation in the 1950s with that of the 1980s: the wealth of indigenous forms described by Puerta Romero (1961) (who studied in detail no less than 300 from a collection of 1 000) was not maintained, and numerous local races of excellent quality are in danger of extinction. The collections made in the second period mentioned barely amount to 12 specimens, although surveys in northern Spain were described in detail (Galicia, Asturias, Basque Country, Navarra) and with relatively good results: the alubias of Toulouse, the pochas of Rioja and the Asturian beans of La Granja could be considered as saved.

The reason for this change was the extensive irrigated cultivation of modern forms of determined growth, for example in El Páramo, León. Until then, the predominant cultivation was typically horticultural, involving branched varieties on small dispersed areas, a situation in which pests and diseases are not generally limiting factors. In the transition to extensive cultivation, both have made their appearance and it was necessary to replace local races with imported cultivars. In El Páramo, for example, the excellent local race, Riñón, has been replaced by Cannellini, which is of lesser quality but resistant to fusarium disease.

What happened with beans for dry seed also occurred in the case of varieties intended for fresh consumption. The branching varieties were replaced by dwarf varieties, and those with flat, curved pods (the exquisite Garrafal), traditional in Spanish cooking, by those with a round cross-section, irrespective of the type of growth. The cause has to be sought once again in the industrial sphere. The straight, round pod makes canning possible without any loss of material and, moreover, if the stalk has a given growth, it can be harvested mechanically.

The situation has now worsened. Direct import at higher prices has had a completely negative effect on Spanish farmers and, consequently, on cultivation. It should be borne in mind in favour of importers and marketers that they require large, uniform quantities which are not found in Spain. The fragmentation of supply, a consequence of genetic diversity, in the haricot bean and in all species dealt with here, plays a curiously negative role in its survival. Those who advocate an ecological agriculture and *in situ* conservation should take this into account.

Prospects for improvement

As in the case of the cowpea, the future seems secure as far as the species is concerned. The developed countries consume the green pods however tasteless they are, generally offering them as an accompaniment to a main dish. Numerous public and private institutions are working on genetic improvement, in particular to obtain low plants with a specific growth and with straight, rounded pods. The IITA is in charge of them within the framework of the developing countries, whatever their use.

In Spain, however, the situation is alarming as regards the conservation of native material. Although the beans of La Granja (the basic ingredient of Asturian fabada) seem out of danger in view of the active research being done on them, and although some commercial seed-producers are carrying out improvement work with some beans of the variety Garrafal (for fresh consumption), in many regions such as El Barco de Avila, La Bañeza, and even in the kitchen gardens of Valencia, the loss of excellent local races may occur in the very short term. The Garbanceras, Riojanas, and Arrocinas of El Barco, the Panchinas and Moritas of Asturia and the Riñón of La Bañeza, all produced for seed, and the numerous and varied Garrafal varieties, as an outstanding example of green beans, may very soon be no more than a number in a gene bank.

This is a curious case in which a stable demand and a high price are causing considerable genetic erosion.

BROAD BEAN
(*Vicia faba*)

Origin of the name

The origin of the name is old in the Latin world. The Romans used to celebrate the *fabarias*, a religious festival in which broad beans used to play a specific role. It is not certain whether the prestigious name of the Fabios derives from *faba*, or vice versa, but in any event one of the most noble Roman families was clearly linked to this species. It was in the Roman world, moreover, that table beans were selected for fresh consumption. The Romans expanded the typically Mediterranean cultivation through their legions, since the seed was used not only for human consumption but also for feeding horses. The Celts, in turn, spread it through the central and Atlantic regions of Europe, to the point that, in some cases, it became known as Celtic grain.

Present situation

On the coast and in the kitchen gardens, the situation of broad beans (*Vicia faba*) coincides with that of the old beans (cowpeas) and with that of the new beans (judías, alubias, etc.). Both were replaced by the former in regions which were a little colder, with lesser rainfall and, in particular, where winter and not summer rains occurred. Broad beans may not need irrigation above 400 mm of precipitation although, obviously, production is to a certain extent dependent on the water they receive. As regards their place in cooking, broad beans, haricot beans and cowpeas have been part of culinary preparations that still exist in traditional dishes. For example, the very popular Asturian *fabada* is made with fabes, which had to be broad beans, the usual name up to 100 or 200 years ago, but which nowadays designates certain varieties of haricot bean.

It is with broad beans that dual use of the legume also began – both for human consumption and for animal feeding – which is unthinkable with *Vigna* and *Phaseolus*, and not only in the Spanish agricultural environment. Broad beans have known every type of use: in this respect, they could be the model of grain legumes. In Spain, they are not at present eaten in the form of whole seeds and boiled with meat and animal fat, but in the recent past they were still prepared in this way (for example, in *fabada*), as in the case of chickpeas, haricot beans and lentils. In other countries, where the shortage of proteins makes it necessary to use those that exist for human consumption, broad beans continue to be eaten like this, just as grain legumes have generally speaking always been eaten. Where there are other sources of proteins, the use of broad beans has been diversified. Some traditional varieties, of which those of Iberian origin – particularly the Aguadulce – stand out because of their quality, have been earmarked for fresh consumption, both as seeds and as whole pods. These are kitchen garden broad beans for direct sale on the market, which in recent times have been prepared as preserved foods. These varieties, which are free of bitter ingredients, are sweet and mild tasting. Those without these characteristics have continued to be fed to animals; of these, types suitable for horses have been selected (which botanists have called Caballares in Spanish, Horse beans in English and Equina in Latin) and others for pigs (called Cochineras, Tick beans or Minor). The division between them (for reasons of convenience in work) has been so great that it is even reflected in separate agronomic and plant improvement categories. The same situation applies in the case of the garden pea.

During collection of the germplasm at the beginning of the 1980s, it was possible to gather together over 1 000 specimens of local populations with a high representation of the types for human consumption, as was to have been expected owing to the reduction observed in those for feedstuffs. Of the grain legumes suitable for animal feeding, broad beans are included among those that suffered most with the arrival of machinery and industrial feedstuffs. Broad beans were the basic feedstuff for horses and oxen and were strong competitors of chickpeas for feeding pigs. The 1973 energy crisis and the rise in the price of American soybeans that same year aroused new interest in the species, not only because of its possibilities as an animal feedstuff, but also for its role in fixing atmospheric nitrogen. ICARDA took charge of it; the EEC subsidized projects in various areas of agronomy and animal feeding, research and working meetings. The exchange of information produced excellent results in broad beans as a feedstuff, and satisfactory results in horticultural broad beans. Private undertakings in particular took charge of the latter. It should be mentioned that there was an interesting transfer of horticultural varieties to the extensive cultivation varieties, given the importance of broad beans in the human diet throughout North Africa and in other countries such as the Sudan and Ethiopia.

At present, there are numerous kitchen garden and feedstuff varieties. The former have been selected from local races, of which the English Windsor and the Italian Policoro deserve mention and, among the Spanish, Muchamiel, Ramillete and, in particular, Aguadulce, which has invaded all the cultivating countries (France, the United Kingdom and Italy), where it is known by this name as well as by the name Seville and others. As a general defect of the species, it should be mentioned that it does not have any commercial types of highly productive determined growth. Although suitable mutants are available and an attempt is being made to introduce them into better cultivars, high-yield mechanical harvesting (which is carried out with peas and haricot beans) is still not feasible.

As regards broad beans intended for animal feeding, the numerous tests carried out by the EEC and by ICARDA have made it possible to obtain numerous high-yield varieties that are competitive with other grains, including cereals. The broad bean cultivation technique, which was very primitive even up to 20 years ago, is now suited to a modern cultivation. Even for its traditional enemies (broomrape [*Orobanche* sp.] in the Mediterranean countries and chocolate spot [*Botrytis fabae*] in the humid climate of Europe) genes have been identified which have effective resistance.

Prospects for improvement

There continues to be a reduction in the cultivated area of broad beans grown for feedstuffs in the European countries, particularly in Spain. There are many reasons for this: the abandonment of traditional cultivation lands; a lack of demand on the part of the compound feedstuffs industries; better profitability of other crops, especially those subsidized by the EEC; etc. The situation is odd, since plant material exists which has been obtained both by public institutions and private undertakings and there is sufficient technical knowledge to achieve a profitable crop. On the one hand, there is no adequate information service for the grower and, on the other hand, there is not a sufficient homogeneous supply for the industrialist. The latter obtains other raw materials more easily and in greater quantities. With a slightly better treatment on the part of the EEC authorities, or if an actual small increase in yield were achieved for the grower, and with a more efficient organization of the supply, the problem could be solved. Otherwise, the attraction that broad bean cultivation still has for the grower – particularly in cases of crisis with other crops – may disappear.

The trade in market garden broad beans is showing a slight market growth and an increase in the interest shown by commercial undertakings which, in some countries (the United Kingdom, for example), have incorporated genes of agronomic importance (determined growth, absence of tannins, resistance). These factors could turn the broad bean into an industrial market garden crop in a short time. The quality of some industrialized products and good acceptance by the consumer allow one to assume that market garden broad beans still have vast prospects. The role played by the Aguadulce varieties in this process should not prevent other local races from being introduced into the work of improvers, industrialists and traders, particularly Ramillete and Muchamiel.

CHICKPEA
(*Cicer arietinum*)

Origin of the name

The Latin *cicer* gives the words Cicero, pois chiche, chickpea and the Spanish word "chícharo", which seems to have been a fairly common name for dry seeds of legumes, including some *Lathyrus* species. The Spanish word "garbanzo" therefore seems to be a pre-Roman indigenous name, since it has no connection with either the Greek or Arabic. The antiquity of the crop in Spain seems evident.

Present situation

In climates that are too dry, broad beans are replaced by chickpeas, which have the additional advantage of a short cycle (from March to June: autumn sowing is a recent introduction).

As in the case of broad beans, chickpeas have been used for human consumption and for animal feeding, particularly cattle and pigs. Modern studies have revealed the high biological value of the chickpea in animal feeding, which is the equivalent without any industrial treatment, for example, to suitably processed soya cakes. Moreover, as in the case of broad beans, the dual use in feeding has caused a clear varietal separation, particularly in the western Mediterranean: white or cream-coloured seeds, very large and wrinkled for human consumption; seeds of varying colour, shape and size (but never very big) and appearance for feedstuffs. The difference affects the cooking time and palatability, the former being easy to cook and having a smooth texture and mild flavour, unlike the latter. This is a consequence of culinary use: in the countries of the western Mediterranean basin, chickpeas continue to be eaten cooked and whole; the representative dishes could be the Spanish *cocido* where the seed is accompanied by meat, animal fat and various vegetables, as in the case of other legumes; and the North African couscous in which it is added to durum wheat semolina and also meat and vegetables. In other regions, it is first of all converted into flour, either to obtain a paste with oil and other condiments (in the eastern Mediterranean), or mixed with other flours to make various types of bread (on the Indian subcontinent).

There are excellent varieties for all these uses. In Spain the quality of the Andalusian "milky whites" and of the Leonese "pedrosillano" (both local races and not cultivars) has enabled them to spread to other areas for cultivation or for use by improvers. Agronomic techniques have for their part developed to the level required of a modern agriculture, and a genuine revolution has even been achieved in this cultivation, with varieties being obtained which are suitable for autumn sowing; are resistant to *Ascochyta* sp. and frost; and which, by utilizing winter rainfall more efficiently, double and sometimes quadruple production. The winter chickpea was bred by ICARDA and the new technology rapidly spread to all producer countries. Its advantages are considerable but ill-informed growers and technical experts often sow in the autumn with local varieties which, since they are not genetically prepared for this, may end up disappearing because of the low temperatures and *Ascochyta* sp. attacks.

Prospects for improvement

In spite of the high price received by the grower for quality chickpeas, it is difficult to explain the reduction in area which is also occurring in the case of this crop. In addition, considerable shortcomings are being noted in marketing. Industrialists complain of the absence of a sufficient, homogeneous supply, which obliges them to resort to imports from Mexico, the United States (California) and Chile. Mexican imports began not less than 20 years ago for political reasons relating to trade. As imported chickpeas were clearly of Spanish descent, similar to the milky whites, introduction on to the market was easy. The imported quantities have for a long time exceeded those produced in the country, which is surprising at a time when new profitable crops are being sought.

Some 40 years ago, Puerta Romero collected about 600 specimens from all over Spain. Ten years ago, he once again collected a similar number, but the genetic richness had suffered a considerable loss: almost all were chickpeas for human consumption whereas, in the first collection, there were splendid examples of chickpeas for animal feedstuffs, but which were lost – as has been shown in so many other collections made by Puerta Romero – as a result of the negligence and ignorance of the agricultural research bodies. At present, the improvement plans for chickpeas for cooking and those for use in the feedstuffs industry and in the food industry in general, as well as the intervention of public and private institutions, suggest that the major local races will be saved and that the crop should be protected from further risks through a good advisory service and adequate marketing. In the case of the developing countries, ICARDA and ICRISAT have succeeded in promoting cultivation worldwide with new varieties and agronomic techniques.

LENTIL
(*Lens culinaris*)

Origin of the name

The derivation from the Latin *lens* is common to European languages.

Present situation

There is no legume more resistant below 350 mm of precipitation and in the coldest climates: the lentil replaces all the others in these conditions. It accompanies barley, which it leaves behind below 250 mm, when it is no longer possible to speak of agriculture in the strict sense. Like the chickpea, it has practically no antinutritional factors except for ingredients which cause flatulence but which are easily tolerated, particularly in the extreme conditions in which it is usually an essential foodstuff.

Its great resistance to severe conditions and its value as a food explain why lentil seed is not used in animal feeding. For the latter purpose, other legumes are used with seeds that are as hard but of lesser value to man because of their antinutritional constituents. These include the one-leaved vetch (*V. monanthos*), bitter vetch (*V. ervilia*), chickling vetch and vetchling (*Lathyrus sativus* and *L. cicera*) and perhaps some others, as old as agriculture itself and in a permanent state of semi-domestication (see previous chapter).

Nowadays, it is not an essential food in Spain, although it is in other parts of the world (ICARDA also concerns itself with the lentil at this level). In Spain, it is consumed in the traditional way as a grain legume: cooked in a mixture with meat and various accompaniments. It continues to be a valued dish, particularly in the case of quality lentils, such as the Verdinas varieties.

Up to ten years ago, the lentil was a crop in the ascendant, the only grain legume to be so in the country. The reason for this was its good quality and considerable acceptance by the consumer. Agronomic techniques had improved but not the varieties, of which only the local races were known. Around 250 specimens were able to be collected, particularly from the northwest of the Castilian plateau, approximately the same and, for once, with the same variation as those represented in Puerta Romero's collections from the 1950s. However, marketing difficulties have meant that, in recent years, the area is also in regression. Imports from Turkey, Chile and recently also from the United States have brought about this change. In this case, it was exclusively a problem of prices. It is regrettable that, in order to promote an imported product, for example, it was even announced that Turkish lentils contained more proteins and were of a better quality for cooking than Spanish lentils. In the case of North American lentils, the way was opened up by the excellent organization of the producers of the northwestern United States. Spanish growers did not know how to react to the sales drives of the imported product.

Prospects for improvement

Contrary to what has happened in the case of closely related species, genetic improvement work on the Spanish lentil has been very limited and has lacked institutional support. It is essential to continue, nevertheless, with the aim of obtaining more productive high-yield cultivars, particularly from the local race Verdinas. This would prevent the import of foreign cultivars, which are accepted because of the absence of Spanish material since, in spite of everything, the crop continues to be profitable. Otherwise, the indigenous material will diminish irremediably.

The improvements in agrarian techniques are also due to private initiatives, which have managed to solve even the problem of mechanization. In Spain, the crop is not affected by pests (the weevil only attacks poorly tended crops) or diseases (except for slight damage caused by fusarium disease). However, elsewhere no resistance has been found against the broomrape (*Orobanche* sp.).

In actual fact, growers are concerned only with prices, imports and marketing.

PEA
(*Pisum sativum*)

Origin of the name

As in the case of the chickpea, the Spanish use a completely original word for this species. The Latin *pisum* has given rise to the names by which the chickpea is known in most of the European languages.

Present situation

Peas are grown over a greater area than that of any other grain legume. They are suited to both kitchen gardens and to semi-arid cold zones. They are not far from reaching the limits of the arid and subtropical zones where lentils and cowpeas, respectively, are grown. Being a legume typical of the Near Eastern agricultural complex, the pea was for centuries intensively bred throughout Europe as a green table grain (and pod) in a similar way to broad beans, subsisting in regions with difficult environmental conditions because it was hardier than the latter. However, unlike broad beans, at the time of the new agriculture propitiated by the industrial revolution (eighteenth century), table peas (i.e. for fresh consumption) were already firmly established in countries that were industrialized early. Unlike broad beans, forms with determined growth were known since the sixteenth century at least, which enabled them to be harvested mechanically whenever this was possible and facilitated their conversion to an extensive horticultural crop. In this connection, the process followed in the case of peas was similar to that of haricot beans.

Dried peas which, like broad beans, are now beginning to be known as products (and wrongly named "fodder", instead of "feed" or simply "seed"), are no longer used for human consumption in Europe, although there have been regions where they were eaten in the traditional way until not long ago. They are still eaten in this way in some Mediterranean areas, although they were never as popular in this respect as lentils, chickpeas, broad beans and haricot beans.

This species has a twofold use (for human consumption and as animal feed), with consequent varietal specialization. Garden peas which are branching or which have determined growth are in big demand. In Spain, hardly any more local races remain, except for various Tirabeques (frequently of unknown origin, rather than indigenous, because of the remote source of imports). Instead there are cultivars that are bred to a greater or lesser extent, mainly of European or American origin. Numerous private and public institutions are undertaking improvement work throughout the developed world, particularly of the dwarf types suitable for mechanical harvesting. Industry incorporated them from the beginning of agricultural mechanization and since the canning industry began rapid expansion. They share this advantageous situation with haricot beans, intended for the same purpose.

Fodder peas have a very different history. Not having had the popularity of other legumes, either for human consumption or as animal feed, they have suffered competition from all of them, since they do not occupy a specific ecological niche that enables them to be the only one possible or the most suitable. Their populations were abandoned by improvers and agronomists after they had taken from them the best of their genetic content for their market gardens. Being a hardy crop, they have resisted the worst soils but, when these were abandoned, they perished with them. It is not surprising that, in the collection of grain legumes made in the early 1980s, the number of samples of peas used in feedstuffs did not even reach 100. No predominant local race is known, and there is considerable genetic poverty in this type of pea in Spain.

Prospects for improvement

It would be appropriate to plant peas on land where there is a requirement for a plant for animal feed, where neither winter broad beans nor chickpeas are able to survive owing to the harshness of the climate and where an autumn-sown crop is needed: the Castilian plateau would be a suitable region for this crop. It is there that the first two Spanish cultivars were bred, and which have thus come into competition with the few foreign cultivars which have been introduced.

The genetic richness of the species is bound to allow rapid improvement since there are no major pests to control (except damage caused by *Pseudomonas* sp.).

Once the appropriate cultivars have been obtained, a rational supply will have to be secured for the feedstuffs industry: peas for animal feeding are of excellent quality. In fact, after the 1973 crisis, the EEC considered the pea as priority protein species, along with broad beans and lupins.

Conclusion

Three conclusions can be drawn from the experience provided by grain legumes for human consumption: the first is that genetic erosion has been and remains extensive and has occurred in relatively few years. The second is that this erosion was the consequence of the world being separated into two parts; one developed and the other developing. The former accepted, conserved, multiplied and improved the species that were suited to agriculture with a largely technological basis. The abandonment by scientists and technical experts of the other species resulted in their being lost insofar as consumption was concerned. However, definitive abandonment was due to a poor agricultural policy and, in particular, deficient marketing.

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Neglected horticultural crops

In the chapter on the processes and causes of the marginalization of Iberian crops, more than 20 horticultural crops are mentioned which could be considered to be in this situation. The authors have selected eight which will be dealt with in detail. Selection was based on a stricter identification of their marginalized nature and choosing from various taxonomic groups that would allow a detailed view of the problem.

Rocket (*Eruca sativa*), garden cress (*Lepidium sativum*), purslane (*Portulaca oleracea*), borage (*Borago officinalis*), alexanders (*Smyrnium olusatrum*), scorzonera or black salsify (*Scorzonera hispanica*), spotted golden thistle (*Scolymus maculatus*) and Spanish salsify or Spanish oyster plant (*Scolymus hispanicus*) are the eight species selected.

ROCKET
(*Eruca sativa*)

Botanical name: *Eruca sativa* Miller

Family: Brassicaceae = Cruciferae

Common names. *English:* rocket, salad rocket, garden rocket; *Spanish:* oruga, oruga común, eruca, roqueta común; *Catalan:* ruqueta; *Basque:* bekarki; *Portuguese:* eruca, rúcula, fedorenta, pinchão (Brazil); *French:* roquette

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Origin of the name

The semantic origin of this plant's name alludes to the oldest crops of the Near East. The Persian *girgir* and Acadian *gingiru* gave the Aramaic, Hebrew and Syrian *gargira*, and from these the Arabic *yiryir* and Latin *eruca*, from which, through Spanish, the words "roqueta" and "oruga" of present-day Spanish appeared.

Properties and uses

This plant is considered to be an excellent stomachic, stimulant and aphrodisiac, and is also used as a diuretic and antiscorbutic. The leaves have a bitter flavour which is made milder by cooking or frying. The seeds are hot, although rather less so than mustard seeds. It contains glucosides, such as allyl sulphocyanate, mineral salts and vitamin C. The oil of the seed contains erucic acid.

Rocket was always considered to be a potent aphrodisiac. In classic antiquity, it was consecrated to Priapus and was planted at the foot of the statue of this deity dedicated to the procreative potential of males. Dioscorides warns that, eaten raw, it stimulates lust and that the seeds have the same power. Columela also refers to its sexually stimulating effect, but is also very well acquainted with its cultivation technique: " ...and rocket and basil also remain in the place where they have been sown and require no other care than manuring and weeding. Moreover, they can be sown not only in autumn, but also in spring...." The Hispano-Romans also compared the aphrodisiac power of rocket precisely with the anaphrodisiac power of lettuce. In Hispano-Visigoth culture, Isidoro de Sevilla supports the use and knowledge of this plant's powers: "... rocket is, so to speak, inflammatory, since it has burning properties and, if consumed frequently in the diet, arouses the sexual appetite. There are two species, one of which is in habitual use while the other is wild with a more bitter taste. Both stimulate sexual appetite."

Irrespective of these effects, rocket has been eaten basically as a vegetable (leaves) and as a spice (leaves and seeds). It is thus an ingredient of "misticanza" (mixed salad), a speciality eaten in Rome since the very foundation of that city. Hispano-Arab agronomists also mention its cultivation, for instance Ibn Hayyay (eleventh century), Ibn Wafid (eleventh and twelfth century) and, of course, Ibn al-Awwam (twelfth century). The latter author mentions the plant's use as a flavouring for musts and syrups, the seed being ground and scattered over the surface of the earthenware jars containing the syrup. He also mentions its flowers being used in a similar way. In the sixteenth century, Alonso de Herrera's *Tratado de agricultura* contains no mention of rocket.

It is used to make sauces in which the leaves are mixed with sugar or honey, vinegar and toasted bread (rocket sauce). In Italy, it is eaten boiled with spaghetti, and then seasoned with garlic and oil. In Spain, it is traditionally used in La Roda and Montealegre del Castillo (Albacete) in the preparation of *gazpachos* of La Mancha, an ancestral dish which includes the meat of partridge and rabbit and unleavened bread (*gazpacho*), with lightly fried rocket. Some authors relate this tradition to primitive fertility rituals.

Nowadays it still remains very much appreciated in various countries of the Mediterranean area, including Italy, Greece and Turkey, where it is eaten mainly in salads and as a garnish for meat. It goes very well with lettuce, chicory, valerian and tomato. Another recipe is potato and rocket salad. In India, it is cultivated to obtain a semi-drying oil from the seeds. At present, most of the rocket grown is for this purpose, and it is considered mainly as a potential oilseed product.

This plant's marginalization as a vegetable in Spain may have been very much connected with its condemnation because of its aphrodisiac properties.

Botanical description

Rocket is an annual herbaceous plant, growing up to 80 cm. The basal leaves occur in a rosette and are lyrate-pinnatifid (those normally eaten in salads); the caulinar leaves are lobulate or dentate. The flowers have white or light yellow petals. The siliquae measure up to 40 mm, are erect, attached to the stem, with a subcylindrical valvar portion and an ensiform face as long as the valves. The seeds measure 1.5 to 2.5 mm and are brown.

The wild form flowers from February to June and the cultivated form right into mid-summer. It is allogamous with a complex system of self-incompatibility, mainly gametophytic, but with some alleles acting sporophytically. The existence of genic male sterility has been verified. The chromosome pattern is $2n = 2x = 22$.

Ecology and phytogeography

Rocket grows spontaneously in places modified by humans: abandoned gardens, waysides, tips and among rubble. It prefers hot, dry climates.

It is distributed all around the Mediterranean, extending to central Europe in the north and as far as Afghanistan and northern India in the east. It has reverted to the wild state in North America, South Africa and Australia. Vavilov described it in central Asia, the Near East and the Mediterranean, the latter being considered its main centre of origin.

It is cultivated mainly in India, and is grown more rarely in Turkey and Greece. It is also cultivated in Italy. In countries such as Spain, France and Great Britain, cultivation is rare.

FIGURE 37

Horticultural crops: A) rocket (*Eruca sativa*), detail of fruit in the silicle; B) garden cress (*Lepidium sativum*), detail of fruit in the silicle; C) purslane (*Portulaca oleracea*)

Genetic diversity

The biggest collections of rocket germplasm are to be found at the Institute of Germplasm in Bari, Italy, at the NBPGR in New Delhi, India, at the Haryana Agricultural University in India and at the VIR in St Petersburg.

There are also smaller collections in Kabul in Afghanistan, Saskatoon in Canada, Gaersleben and Braunschweig in Germany, Tapioszele in Hungary, Islamabad in Pakistan, Blonie in Poland and Alnarp in Sweden. A small collection of species of *Eruca*, including *E. sativa*, is to be found at the Universidad Politécnica de Madrid and there is also germplasm from wild populations of the genus at the Córdoba Botanical Garden.

Collecting expeditions have continued. In 1985, 25 samples of indigenous germplasm of *E. sativa* were collected in the northeastern Sudan.

In an analysis using the D^2 statistic of Mahalanobis, out of 99 lines of rocket no correlation was found between genetic diversity for 12 characters associated with production and geographical origin.

There is wide variability as regards the characters of the siliqua and its stability, and a strong interaction with the cultivation conditions. Similarly, there is wide genetic variability for seed production per plant and related characters.

An important group of studies is attempting to use *E. sativa* as a genetic resource for improving other crucifers. In this way, intergeneric hybrids have been obtained with *Raphanus sativus*, *Brassica campestris* and *B. oleracea*. Somatic hybrids have been obtained through the fusion of protoplasts with *B. napus* and *B. juncea*.

There are lines of rocket (T27) known which are resistant to mustard aphid and tolerant of several stress conditions as well as *Fusarium oxysporum*. Such lines may also be a source of genes that are transferable to species of *Brassica*.

Cultivation practices

Rocket is a very hardy plant which requires little care. It is generally sown direct in late winter or early spring, in shallow furrows. To encourage emergence, it is advisable to cover with light sieved soil. It requires little irrigation and manuring. It is usually hoed by hand.

The young leaves are harvested in spring.

Prospects for improvement

The use of rocket as a vegetable, salad or spice has been marginalized, possibly for moral or religious reasons, and its recovery is limited by local gastronomic tradition, which is not always able to appreciate its characteristic bitter flavour. This is due to glucosinolates and the high content of mineral salts.

The development of cultivars with a low allyl sulphocyanate content does not appear to be an improvement objective since, even though the plant would be rendered innocuous, it would lose its individual identity.

In fact, a wide variability has been observed as regards both erucic acid content and glucosinolate content in 128 rocket specimens from Pakistan. Rocket already has a low content of these constituents, and the local inhabitants clearly distinguish this species from other more bitter crucifers. Its use can be increased only through the promotion of the traditional dishes in which it appears.

The use of agronomic techniques such as nitrogen fertilization and shading would enable younger, more juicy rosettes to be obtained which have a milder taste and are more palatable.

The work on genetic improvement for the use of "rocket" as a vegetable is very limited, if we exclude the development of *in vitro* cultivation, which has made it possible to regenerate normal diploid plants from isolated protoplasts of leaf mesophyll.

GARDEN CRESS (*Lepidium sativum*)

Botanical name: *Lepidium sativum* L.

Family: Brassicaceae = Cruciferae

Common names. *English:* cress, common cress, garden cress, land cress, pepper cress; *Spanish:* mastuerzo, mastuerzo hortense, lepidio, berro de jardín (Spain), berro de tierra, berro hortense (Argentina), escobilla (Costa Rica); *Catalan:* morritort, morrisà, *Portuguese* and *Galician:* masturco, mastruco, agrião-mouro, herba do esforzo; *Portuguese:* mastruco do Sul, agrião (Brazil); *Basque:* buminka, beatzecrexu

Origin of the name

Cultivation of this species, which is native to Southwest Asia (perhaps Persia) and which spread many centuries ago to western Europe, is very old, as is shown by the philological trace of its names in different Indo-European languages. These include the Persian word *turehtezuk*, the Greek *kardamon*, the Latin *nasturtium* and Arabic *tuffa'* and *hurf*. In some languages there is a degree of confusion with watercress. It seems that the meaning of the word *nasturtium* (*nasum torcere*, because its smell causes the nose to turn up) must have been applied initially to garden cress, as both Pliny and Isidoro de Sevilla explain. The confusion remains with the terms used by the Hispano-Arabs. The word *hurf* is applied without distinction to watercress and garden cress (several species certainly of up to three different genera: *Nasturtium*, *Lepidium* and *Cardaria*). Thus the medieval agronomists of Andalusia went as far as differentiating between several *hurf*, such as *hurf abyad*, *hurf babili*, *hurf madani*....

Properties, uses and cultivation

Xenophon (400 BC) mentions that the Persians used to eat this plant even before bread was known. It was also familiar to the Egyptians and was very much appreciated by the Greeks and Romans, who were very fond of banquets rich in spices and spicy salads. Columela (first century) makes direct reference to the cultivation of garden cress. In *Los doce libros de Agricultura*, he writes: " ...immediately after the calends of January, garden cress is sown out... when you have transplanted it before the calends of March, you will be able to harvest it like chives, but less often... it must not be cut after the calends of November because it dies from frosts, but can resist for two years if it is hoed and manured carefully... there are also many sites where it lives for up to ten years" (Book XI). The latter statements seem to indicate that he is also speaking of the perennial species *L. latifolium*, as *L. sativum* is an annual.

Almost all of the Andalusian agronomists of the Middle Ages (Ibn Hayyay, Ibn Wafid, Ibn al-Baytar, Ibn Luyun, Ibn al-Awwam) and many of the doctors, such as Maimonides, mention garden cress. Ibn al-Awwam also includes references from Abu al-Jair, Abu Abdalah as well as from Nabataean agriculture and, among other comments, he says: "Garden cress is sown between February and April (in January in Seville). It has small seeds which are mixed with earth for sowing to prevent the wind carrying them away.... It is harvested in May and is grown between ridges, in combination/conjunction with flax cultivation."

Many of the authors of the old oriental and Mediterranean cultures emphasized the medicinal properties of cress, especially as an antiscorbutic, depurative and stimulant. Columela notes its vermifugal powers. Ibn al-Awwam refers to certain apparently antihistaminic properties, since it was used against insect bites and also as an insect repellent, in the form of a fumigant. It was perhaps Ibn al-Baytar, an Andalusian botanist (eighth century), who collected most information on its properties, summarizing the opinions of other authors such as El Farcy, who says that it incites coitus and stimulates the appetite; Ibn Massa, according to whom it dissipates colic and gets rid of tapeworms and other intestinal worms; or Ibn Massouih, who mentions that it eliminates viscous humours. Ibn al-Baytar also says that it is administered against leprosy, is useful for renal "cooling" and that, if hair is washed with garden cress water, it is "purified" and any loss is arrested.

In Iran and Morocco, the seeds are used as an aphrodisiac. In former Abyssinia, an edible oil was obtained from the seeds. In Eritrea, it was used as a dyestuff plant. Some Arab scholars have attributed garden cress's reputation among Muslims to the fact that it was directly recommended by the Prophet.

Garden cress's main use was always as an aromatic and slightly pungent plant. Not only in antiquity but also in the Middle Ages it enjoyed considerable prestige on royal tables. The young leaves were used for salads. The ancient Spartans ate them with bread. This use still continues and they are also eaten with bread and butter or with bread to which lemon, vinegar or sugar is added. However, it is mainly used nowadays in the seedling stage, the succulent hypocotyls being added to salads and as a garnish and decoration for dishes.

The roots, seeds and leaves have been used as a spicy condiment. Columela explains how *oxygala*, a type of curd cheese with herbs, was prepared: "Some people, after collecting cultivated or even wild garden cress, dry it in the shade and then, after removing the stem, add its leaves to brine, squeezing them and placing them in milk without any other seasoning, and adding the amount of salt they consider sufficient.... Others mix fresh leaves of cultivated cress with sweetened milk in a pot...".

L. latifolium L. stands out for its horticultural interest; although it grows spontaneously on the edges of rivers and lakes, it is also occasionally grown in the same way as *L. sativum*. Its young leaves can be used for salads; the ancient Greeks and Romans used to grow it for this purpose. Its leaves and seeds were also used as a spicy condiment. Several sauces are prepared with its leaves, including in particular the bitter sauce of the paschal lamb of the Jews. The seeds of this species were known in England as the poor people's pepper. The roots have been used on occasion as a substitute for radish.

In the fifteenth century, we know through Alonso de Herrera that garden cress was one of the vegetables most widely eaten in Castile. During the sixteenth century, obstinate attempts were made to introduce it into America. Right up to the beginning of the nineteenth century, its cultivation in Spain continued to be important, since Boutelou and Boutelou (1801) deal specifically with this crop in their *Tratado de la huerta*, commenting on the existence of several cultivars. At present, the cultivation of cress is very occasional in countries such as Spain and France. Water cress, in competition with garden cress, has eclipsed the cultivation of the latter. However, this is not the case in other central European countries or the United Kingdom, where its use is normal and the system of cultivation has changed substantially.

Botanical description

Cress is an annual, erect herbaceous plant, growing up to 50 cm. The basal leaves have long petioles and are lyrate-pinnatipartite; the caulinar leaves are laciniate-pinnate while the upper leaves are entire. The inflorescences are in dense racemes. The flowers have white or slightly pink petals, measuring 2 mm. The siliquae measure 5 to 6 × 4 mm, are elliptical, alate from the upper half, and glabrous. Cress flowers in the wild state between March and June.

It is an allogamous plant with self-compatible and self-incompatible forms and with various degrees of tolerance to prolonged autogamy. There are diploid forms, 2n = 2x = 16, and tetraploid forms, 2n = 4x = 32. A degree of variability is noted in the character of the basal leaves which are cleft or split to a greater or lesser degree, a character which is controlled by a single incompletely dominant gene.

Ecology and phytogeography

Cress is a plant that is well suited to all soils and climates, although it does not tolerate frosts. In temperate conditions, it has a very rapid growth rate. It grows subspontaneously in areas transformed by humans, close to crops or human settlements. It appears in this way on the Iberian peninsula, mainly in the eastern regions.

Wild cress extends from the Sudan to the Himalayas. Most authors consider it to be a native of western Asia, whence it passed very quickly to Europe and the rest of Asia as a secondary crop, probably associated with cultivars of flax. Vavilov considers its main centre to be Ethiopia, where he found the widest variability; the Near East, central Asia and the Mediterranean are considered secondary centres. It is now naturalized in numerous parts of Europe, including the British Isles.

Genetic diversity

The genus *Lepidium* is made up of about 150 species, distributed throughout almost all temperate and subtropical regions of the world. On the Iberian peninsula and the Balearic Islands, at least 20 species or subspecies exist among the autochthonous and allochthonous taxa, some genetically close to *L. sativum*. Seven of them are exclusively endemic to the peninsula or, at the very most, are common with North Africa. Other close species are *L. campestre* (L.) R. Br. and *L. ruderale* L. which also have edible leaves. The leaves of *L. campestre* are used to prepare excellent sauces for fish.

Common cress (*L. sativum* L.), with regard to the anatomy of the leaf, stem and root, has been divided into three botanical varieties: *vulgare*, *crispum* and *latifolium*. The latter is the most mesomorphic, *crispum* the most xeromorphic and *vulgare* intermediate.

At present, most of the studies on the variability and development of new cultivars are being carried out in liaison with the VIR of St Petersburg, where there is a good collection of material. Of the 350 forms of garden cress studied in the Ukraine, Uzkolistnyti 3 was the best, being highly productive and of good quality. It is being used as the basis of improvement programmes, as it appreciably surpasses the best Soviet varieties in production and quality. Other cultivars well suited to European Russia are Tuikers Grootbladige (broad-leaved) and the lines Mestnyi k137, k106 and k115. Of the types most cultivated in Europe, Early European, Eastern, Dagestan and Entire Leaved stand out, being distinguished by the length and shape of the leaf, earliness and susceptibility to cold. In Western Europe, one broad-leaved type is especially appreciated (Broad Leaved French) as are curly types (Curly Leaved), the latter being used extensively to garnish dishes. In Africa, there are red, white and black varieties.

This crop is also arousing interest in Japan, and collecting expeditions to Nepal have been organized. Some specimens collected during an expedition to Iraq in 1986 are now stored in Abu Ghraib and in Gratersleben, Germany. There are also small collections of *L. sativum* in the PGRC in Addis Ababa (Ethiopia), at the ARARI of İzmir in Turkey and in Bari, Italy. At the Universidad Politécnica de Madrid there are accessions of 20 species of *Lepidium*, while the BGV of the Córdoba Botanical Garden keeps germplasm of the southern Iberian species of the genus.

Cultivation practices

Cress is an easily grown plant with few requirements. It can be broadcast after the winter frosts or throughout the year in temperate climates. However, Boutelou and Boutelou (1801) were already recommending sowing in shallow furrows, which enables surplus plants to be thinned out and facilitates hoeing. Sowing has to be repeated every 15 to 20 days so that there is no shortage of young shoots and new leaves for salads – the leaves of earlier sowings begin to get tough and are no longer usable. The seed sprouts four or six days after sowing, depending on the season, and the leaves are ready for consumption after two or three weeks.

The usual form of cultivation continues to be as described, with 15 to 20 cm between rows and the use of irrigation in the summer, since they are lightly rooted seedlings which can dry up in a few days. Its growth is very rapid and harvesting can begin in the same month as sowing, with yields reaching 6 tonnes per hectare.

Prospects for improvement

Most of the genetic improvement work on garden cress is being carried out in the CIS, with little or no work being done at present in the countries of western Europe. Mainly early cultivars with a prolonged production period and better cold tolerance are being developed.

Cress can be grown and used like white mustard. It germinates more slowly at low temperatures, the emergence period being three or four days longer. Shortening this period is an interesting improvement objective.

However, cress's recovery and its greater presence on markets mainly depends on a modification of cultivation and marketing techniques. In countries such as the United Kingdom, where this vegetable is normally to be found at the markets, cultivation takes place in greenhouses throughout the year. The whole succulent hypocotyls of the very young seedlings are eaten. The seed is placed on the soil surface on soft, level beds. It is finely sprinkled with water and then covered with sackcloth which has been steam-sterilized and moistened. The latter is frequently wetted to maintain moisture and is removed when the seedlings reach 4 to 5 cm in height (after approximately seven days in spring and autumn and ten days in winter). The yellowish leaves turn green after two to three days.

The cress is harvested when the first pair of cotyledon leaves have developed and it is marketed in small bags or trays, sometimes together with seedlings of white mustard.

Garden cress and white pepper are sometimes sown in the plastic trays or bags in which they will be sold, generally in peat with a nutrient solution.

PURSLANE
(*Portulaca oleracea*)

Botanical name: *Portulaca oleracea* L.
Family: Portulacaceae
Common names. *English:* purslane, purslave, pursley, pusley; *Spanish and Catalan:* verdolaga, verdalaga, buglosa, hierba grasa, porcelana, tarfela, peplide (Spain), colchón de niño (El Salvador), flor de las once (Colombia), flor de un día, lega (Argentina); *Portuguese* and *Galician:* beldroega, bredo-femea, baldroaga; *Basque:* ketozki, ketorki, getozca; *French:* pourpier, portulache

Origin of the name

The diversity of names and meanings already gives an idea of the age and geographical dispersion of purslane's cultivation or use. On the basis of historical, archaeological and linguistic documentation, De Candolle thought that this species was cultivated more than 4 000 years ago. Its common names come from different roots: *lonica* or *louina* (Sanskrit), *koursa* (Hindustani), *kholza* and *perpehen* (Persian), *adrajne agria* (Greek), *portulaca* (Latin, which means "little door", because of the way its capsule opens). The Arabs in the Middle Ages called it *baqla hamqa'*, which means "mad" or "crazy vegetable" because of the fact that its branches spread over the ground without any control. The Hispano-Arabs of Al-Andalus (from the tenth to fifteenth century) used the name *riyla*, which means "foot", most certainly because of its dactyliform leaves, and also *furfir*, *farfan*, *farfag*, *farfagin*, derived from the Persian *perpehen*. They also called it *missita*, which means "mixed", because it is sometimes found growing in gardens and sometimes growing wild. In Spanish, names such as verdilacas, yerba aurato and yerba orate are known (which again mean "crazy herb").

Properties, uses and cultivation

As a medicinal plant, it is considered to have antiscorbutic, diuretic and cooling properties. Being rich in mineral salts and with a high water content (95 percent) and mucilage content, it has emollient and soothing properties for irritations of the bladder and urinary tract. It is also used to regulate the bowels. Dioscorides already recognized its medicinal powers: these were anti-inflammatory (eyes) and analgesic (headache), emollient and soothing, antifebrifuge (in juice) and anthelmintic. He also says that "it reduces the desire to fornicate". In the latter sense, other authors also mention its anaphrodisiac powers (1837 Codex of the Spanish Pharmacopoeia), including this plant among the "four cold seeds", together with chicory, endive and lettuce. The anaphrodisiac effect is perhaps due to the presence of norepinephrin, a precursor of adrenalin, which causes a reduction in the blood flow through constriction of the main arteries. It is also mentioned by Maimonides. In the Middle Ages, the pharmacists of Cairo used to sell purslane seed for various uses, recommending it in particular as a vermifuge. Laguna and Leclerc also recognized its different medicinal properties, especially the anti-inflammatory ones, in mixtures prepared with plantain, violets and gourds. Its magical powers have also been mentioned, as a charm against evil spirits and for dispelling nightmares if placed in the bed.

However, in addition to its medicinal powers, it is also a vegetable, a weed and a food for pigs.

Columela writes in his poem on the garden: "Already the juicy purslane covers the dry beds"; and in *Los doce libros de agricultura*: "Leafy purslane appeases the plot's thirst" (Book X); and in Book XI he gives a recipe for preserving it in vinegar and salt. Paladio refers to it exclusively because of its mucilaginous, medicinal and veterinary properties. Similar references are found in Kastos, taking up the Byzantine tradition. Isidoro de Sevilla mentions it without giving any information on its cultivation. In short, such a summary reference to the Hispano-Roman and Hispano-Visigoth tradition regarding purslane is surprising.

It is the writers of oriental and Arabic treatises who concerned themselves most with this vegetable. Ibn Wahsiyya describes its cultivation in the Near East, presenting it as a summer crop. Most of the Hispano-Arab agronomists deal with this plant. Arib (tenth century) mentions it in his *Calendario agrícola*. Al Zahrawi and Ibn Hayyay (eleventh century) also mention it. Ibn Bassal (eleventh century) deals extensively with its cultivation, already recognizing a certain intraspecific variability (he distinguishes early and late varieties), setting out its temperature and water requirements (summer cultivation and irrigation or vegetable garden), drawing up a sowing calendar which extends from March to August and demonstrating the practice of two basic cultivation periods, depending on whether the aim is to produce seed or to produce for human consumption. Sowing quantities and manuring and irrigation requirements also appear and are dealt with in great detail by the author. Ibn Wafid (Hispano-Arab agronomist of the eleventh and twelfth centuries) mentions it under the names *baqla hamqa'* and *missita*. Ibn al-Awwam, in his *Kitab al-Filaha*, recalls that it is mentioned by almost all the Arab authors and refers to different varieties. He uses the adjectives "mild", "vain" and "blessed".

After the sixteenth century, cultivation of purslane was gradually lost in Spain. Alonso de Herrera (sixteenth century), for example, makes no reference to it while Boutelou and Boutelou (1801) say that "purslane, which is not at all appreciated in Spain, is one of the crops which, in England and other countries further north, need to be cultivated in frames and hotbeds in order to bring forward their vegetation artificially"; and further on: "on this land, it is not usual to cultivate purslane other than using those that have grown at random among other plants cultivated with more care". In spite of Spanish disregard for this plant, it is still valued in many Latin American countries where it was introduced.

Purslane has been eaten as a vegetable, particularly fresh. In England in the seventeenth century, the cooks of Charles II used to add its leaves to all salads, perhaps to satisfy the king's taste or else for its digestive properties. In this recipe, the chopped young leaves were mixed with double the amount of leaves of lettuce, chervil, borage flowers and marigold petals, the mixture being dressed with oil and lemon juice. The recipe resembles that mentioned by Tirso de Molina: "I will have green coriander, garden cress, purslane, borage and mint added to it."

Not only the leaves, but also the stems and rootless plantlets can be eaten raw and fresh. Columela mentions their being eaten pickled with salt and vinegar. Purslane has a pleasant acidic flavour and is very juicy. In Spain, it is usually eaten at a more advanced stage of growth, after cooking. It is also delicious boiled and in omelettes. Sautéed in butter or fried, it is used in soups, broths, salads and sauces. Together with sorrel, it forms part of the French soup *bonne femme*. Recipes are also known for purslane and pea soups.

To complete the range of its applications, one could mention its use as an insecticide, in which case its juice is poured on to anthills, and also its ornamental use in Roman and medieval gardens.

At present in Spain, it is basically a volunteer species (weed) among summer irrigated crops, and its consumption is gradually declining; this is also the case with individuals collected from wild populations.

Botanical description

Purslane is an annual, herbaceous plant, with branched, decumbent or fairly ascending stems of up to 50 cm, and which are reddish, fleshy and glabrous. The leaves measure 0.5 to 3.3 × 0.2 to 1.5 cm, are obovate, entire and fairly papillose. The flowers are yellow and solitary or in axillary groups of two or three. The fruit is in a capsule (pyxidium) of up to 7 mm. The seeds measure 0.6 to 1 mm; they are reniform, black, and maintain their germinating capacity for eight to ten years. Of orthodox behaviour in germination, their viability is maintained much more if they are stored dry at a low temperature.

Ecology and phytogeography

Purslane was one of the most widespread horticultural plants in the Old World since distant times. It was taken to America where it was naturalized, as in Europe, in gardens, among rubble and at waysides. It originates from the region extending from the western Himalayas to southern Russia and Greece. In eastern Asia it does not seem to be spontaneous. In Greece it is spontaneous and cultivated. Vavilov (1951) categorizes it in the Mediterranean countries of the Near East and central Asia as a weed and vegetable.

Nowadays it is distributed over the hot temperate zones of a great part of the world. Together with other species of the genus it occurs as a weed in the majority of tropical and subtropical countries.

It is cultivated in the United Kingdom, the Netherlands and other European countries. It is a popular winter vegetable in northern India. In Spain, it very frequently occurs as a volunteer, but it is very rare as a crop.

Genetic diversity

Little work has been done on the management of purslane's extraspecific variability. Apparently, without any aim at improvement, protoplast fusion of the genera *Portulaca* and *Nicotiana* has been attempted, and heterokaryons and the first division have been observed, but it is not clear whether multiple divisions occurred.

Nevertheless, there is an enormous intrageneric variability. The genus *Portulaca* is cosmopolitan and many species are grown as a vegetable. Thus, *P. afra* Jacq., *P. pilosa* L. and *P. tuberosa* Roxb. in southern Africa and *P. quadrifida* L. in tropical Africa; *P. retusa* Engelm. in North America and *P. pilosa* L. in South America; *P. napiformis* Muell. in Australia; and *P. lutea* Forst in Polynesia. *P. quadrifida* L. is cultivated in many tropical regions.

Within *P. oleracea* and in its wild populations, Danin and Baker distinguish five subspecies (*oleracea*, *papillato-stellulata*, *stellata*, *granulato-stellulata* and *nitida*), on the basis of the seed size and structure of the testa. Recognition of these subspecies is somewhat questionable, especially if we take into account their sympatric character. Generally speaking, the existence of a single *P. oleracea* complex with several varieties is accepted; it includes: var. *oleracea*, which is widespread as a weed; and var. *sativa* (Haw.) Celak, which is cultivated as a vegetable and has a bigger and erect habit.

In a chemotaxonomic study comparing proteins and free amino acids, Prabhakar and Ramayya (1988) found that, within the complex *P. oleracea*, the var. *ophemera* is distinct from the var. *oleracea* and *sativa*.

In the var. *sativa*, it is usual to distinguish two types which can be differentiated by their colouring: green purslane and golden purslane. However, it seems that colour depends basically on exposure to the sun and is more an environmental than a genetic characteristic. Some markets, such as the French market, appreciate red in particular.

In the commercial catalogues of seed firms, cultivars of this horticultural plant are not usually offered.

Girenko (1980) has described the intraspecific diversity and composition of cultivars in various climatic zones of the CIS, along with another set of data of agricultural interest.[1]

Extensive work also has to be done on the recovery and conservation of purslane germplasm. In 1985, as part of a joint project with the IBPGR, a mission of the Agricultural Research Corporation collected indigenous germplasm of *P. oleracea* in the northeastern region of the Sudan. At ARARI in Izmir, Turkey, some accessions of *P. oleracea* are conserved.

Cultivation practices

This is a vegetable which develops rapidly in hot environments. Cultivation is very simple, entailing the necessary hoeing and irrigation on light, rich soils which encourage emergence.

It can be grown in greenhouses and may be broadcast or sown by burying the seeds with light

[1] This article, published in 1988, has not been translated from Russian.

pressure. A first and second irrigation are essential and must be carried out either by sprinkler or by hand. In order to ensure moisture during emergence, the plots are sometimes covered with wet sackcloth. The seeds germinate quickly and have to be raised up to accelerate emergence and development. The plantlets are harvested when four or five leaves have formed which, with suitable temperatures, is achieved in about 20 days. It is possible to cover a long production period by staggered sowing.

In temperate areas in central Europe around April, when the frosts are over, cultivation also takes place in the open air with direct broadcasting (10 g per m^2). Moisture must be ensured during emergence. Later, when the seedlings have reached the mid-point in their growth, they tolerate water shortages well. In this type of cultivation, the plant is normally allowed to develop and the stalks are harvested throughout the summer. If the plant is not pulled up, it sprouts again.

The crop's biggest enemies are low temperatures and weeds, which require as many hoeings as necessary. Pests and diseases do not appear to constitute important limitations.

Prospects for improvement

Cultivation does not present any technical difficulty preventing restoration of this vegetable's use. In experimental tests carried out by the authors on the southeastern coast of Spain, uniform production of seedlings of between 6 and 8 cm was obtainable after a month or so during the winter and spring in an unheated polyethylene greenhouse.

This type of cultivation is the one which may be most readily acceptable on western markets, provided clean rootless seedlings are offered, appropriately packaged in trays covered with plastic film. Under these conditions, they keep well at low temperatures for a couple of weeks.

This type of product is practically unknown to the consumer and yet it is the most suitable for salads. If plants or shoots of plants developed under high temperature conditions are used, they may have excessive mucilage and an unpleasant texture. The plantlets have a milder flavour and texture which make them more appetizing.

Where plant material is concerned, practically everything remains to be done, since very little improvement work has been carried out recently.

BORAGE
(*Borago officinalis*)

Botanical name: *Borago officinalis* L.
Family: Boraginaceae
Common names. *English:* borage, cool tankard; *Spanish:* borraja, borraja común, borraga, borracha, bora, corrago, alcohelo, flores cordiales; *Catalan:* borratja, borraina, pa-i-pexet; *Basque:* borrai, borroin, murrum, assunasa, porraiña; *Portuguese* and *Galician:* borrage, borragem, erva borragem, borraxa

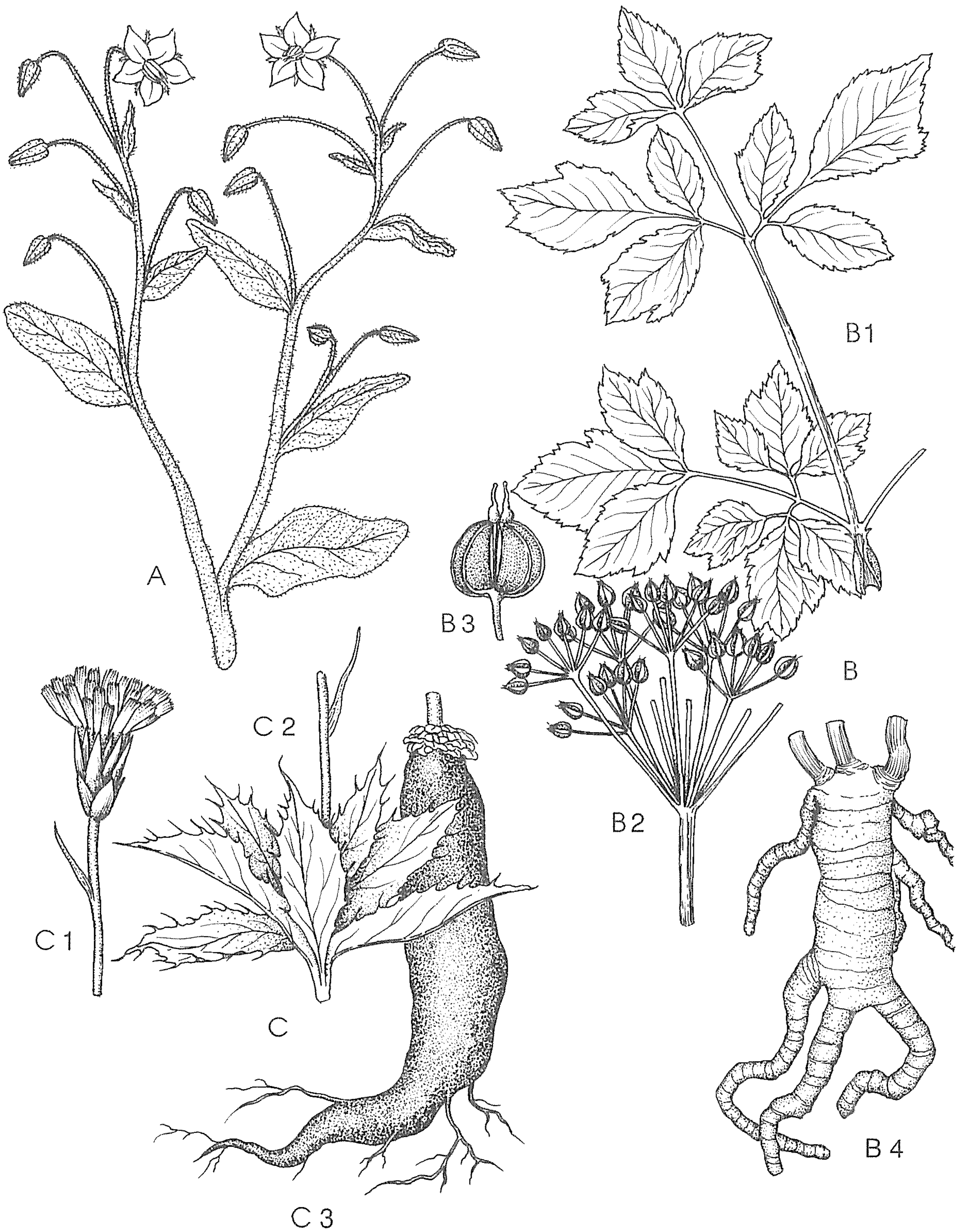
Properties, uses and cultivation

Borage is attributed with sudorific (flowers), diuretic (leaves and petioles) and emollient properties (cataplasms of leaves). It contains substantial mucilage, tannin, potassium and magnesium salts and traces of essence. The seeds contain up to 23 percent linoleic acid.

Pharmacologists in past times used to include borage within the "four pectoral flowers", and it was also strongly recommended in cases of rheumatism, in which case the fresh leaves were applied as a poultice, since they lose their properties when dry. The flowers and seeds had a reputation as euphoriants and were added to wine for this purpose. Some authors think that borage is the plant which the Greeks called *eufrosinon* and which, according to Pliny, "made men joy-

FIGURE 38

Horticultural crops: A) borage (*Borago officinalis*); B) alexanders (*Smyrnium olusatrum*); B1) leaves; B2) inflorescences in the umbel; B) fruit; B4) root; C) scorzonera (*Scorzonera hispanica*); C1) capitulum; C2) basal rosette of leaves; C3) root



ous and happy". One Greek proverb used to say: "I, borage, always give courage." In sixteenth-century Spain, it was still attributed with this property.

Thus, Alonso de Herrera (1981 [1513]) states that borages "are healthier than any other vegetable and, in truth, it can be said that in many cases they are not appreciated because these powers, which are many, are unknown". He also mentions some of these: "When raw, they engender a very singular blood, and more so when cooked with a good mutton or capons, and for this reason they are very good for old people... and if their seed is drunk in wine, it cheers the heart greatly...". The question arises as to whether the vegetable's virtues might not be due to the other ingredient which accompanied it.

In actual fact, its effects cannot be very obvious, since "in many cases they are not appreciated". The mildness of its action perhaps explains the well-known Spanish expression "it is borage water" to indicate that something has come to nothing. For example, Boutelou and Boutelou (1801) explained: "In ancient times it was very often used in medicine, but nowadays it is practically forgotten since it does not produce the effects for which it was applied in those days."

As a food vegetable, the origin of its cultivation has not been pinpointed. Although it is unclear whether the Greeks and Romans made medicinal use of this plant, it is more certain that they did not cultivate it, since none of the writers of treatises such as Columela or Paladio referred to it, although some authors attribute a Latin etymology to *borago* (derived from *borra* = rigid hair, because of the characteristic hairiness of the whole plant). Other authors support an Arabic etymology, from *abu* = father and *rash* = sweat, because of the sudorific property of its flowers. Some historians even thought that the plant came from Africa during the Middle Ages. However, there is no doubt that the plant is native to Spain and that, around the twelfth century, the Andalusian Muslims were not growing it. Indeed, in his *Kitab al-Filaha*, Ibn al-Awwam makes a single reference to it, treating it as a wild plant which could be used in times of famine. Other Andalusian agronomists and doctors such as Ibn Hayyay (tenth century), Ibn Wafid (eleventh to twelfth centuries) and Maimonides (tenth century) seem to mention it, but there is a degree of confusion regarding its name, *lisan al-lawr* (ox tongue), which may refer to both *Borago officinalis* and *Anchusa officinalis* or *A. italica*.

Consequently, borage must not have been cultivated until after the twelfth century. It is known to have been grown in Castile in the fifteenth century and, in 1539, Alonso de Herrera gave an extensive description of its cultivation and properties. It was one of the first vegetables taken to America by the Spanish; as early as 1494 it was being grown in the gardens of La Isabela, the first city founded on American soil. In the seventeenth century, Cobo (1953 [1662]) also stated that borage had adapted to Latin America. In the eighteenth century, it was frequently grown but had already lost importance.

Borage is grown for its leaves and stalks which are eaten as a vegetable. The young leaves can be eaten raw in salad dressed with olive oil, giving an aroma and flavour similar to cucumber. They should be chopped, since they are not very appealing whole because of their hairiness. They are used cooked in soups, as a garnish for meats and also in *olla*, a kind of stew. The leaves cooked in batter and served with hot or grated cheese are delicious. Similarly, borage dumplings can be made, while its finely chopped leaves can be cooked with almond milk to make an exquisite soup or used to make an excellent borage omelette.

However, nowadays leaf petioles are the part of the plant most used and lend themselves to most of the uses stated.

The flowers are used to garnish dishes and prepare an exquisite dessert. Genders (1988) suggests a recipe for borage tart. In some regions, a dessert is also prepared by frying the leaves, to which sugar or honey is added, in the same way as the *paparajotes* of Murcia, but using borage instead of lemon leaves. In Majorca, according to Font Quer (1990) the leaves are used to make fritters by preparing a mixture with beaten eggs and wheat flour and then frying the leaves thus coated in hot oil and sprinkling them with sugar and cinnamon.

Borage is also a honey-producing plant, the flowers and roots produce dye, while the active synthesis of linoleic acid – of pharmacological and cosmetic interest – occurs in the ovary, which explains the high content of linoleic acid in the seeds.

Botanical description

Borage is a sturdy, annual herbaceous plant. Almost all the plant is covered with stiff hairs. It has a taproot and erect, sturdy stems which reach 20 to 100 cm and are sometimes branched. It has ovate or lanceolate, petiolate basal leaves in a rosette which grow up to 25 cm. The upper caulinar leaves surrounding the stem are sessile. The flowers are a bright celestial blue on branched tops. Flowering occurs from spring to autumn. The fruit contains four oblongo-ovoid nucules measuring 4 × 2.5 mm.

Borage is an allogamous plant, which has hermaphrodite flowers with exserted stamens. It has a self-incompatibility system controlled by numerous genes. Pollination is predominantly entomophilous (bees).

The plant is propagated from seed. Seed collection is laborious, since the seeds drop easily. Sixty-five seeds weigh 1 g; 1 litre of seeds weighs around 430 g. In commercial storage conditions, germination capacity remains high for eight to ten years. Its behaviour is orthodox in storage. The seed germinates very quickly, without any dormancy problems. The chromosome pattern is 2n = 2x = 16.

Ecology and phytogeography

In its spontaneous or subspontaneous form, borage grows on uncultivated land, embankments, fallow land, wasteland, garden edges, waysides and among ruins.

It is native to the Mediterranean region but has been naturalized in the hot zones of western, central and eastern Europe, sometimes with unstable escapes northwards. It is also found in Southwest Asia, Macronesia and North America.

Cultivation of borage as a vegetable is limited to certain regions of the Netherlands, France, Spain and Latin America, being unknown in the rest of the world.

In Spain, it is grown mainly in the Ebro valley, in the provinces of Zaragoza, Logroño and Navarra. The total cultivated area in 1987 was 303 ha and production 7 818 tonnes.

In recent years, some expansion of cultivation towards Andalusia has been noted, particularly in Almería. Sheltered cultivation is beginning to be carried out, with excellent results.

Genetic diversity

The genus *Borago* has only two Mediterranean species. In humid areas of Corsica and Sardinia, *B. pygmaea* (DC.) Chater & W. Greuter, a perennial with decumbent stems, is found.

Borago officinalis L. is a very variable species. There are varieties characterized by the flower colour. Although they are generally bright blue, there are also types with white and pink flowers. However, these are very heterogeneous populations with a great diversity in habit, vigour and development of the plant, shape, colour and size of the limb and leaf petiole, flowering, etc.

The cultivar Flor Blanca, which is marketed in Spain, has leaves with petioles of 40 to 50 cm in length and 1.5 cm in width. The plant grows to a height of around 50 to 60 cm.

In the gene bank of the SIA at the Diputación General de Aragón (Zaragoza), there is a small collection of accessions of this vegetable.

Cultivation practices

Borage is a very hardy plant which is suited to all types of soil, although it grows best on clayey-muddy soils. It prefers land that is rich in organic matter. It tolerates low temperatures, down to -50°C, and starts to sprout again when the temperature rises.

In Spain, direct sowing is used. The ground should be prepared with a basal dressing using about 50 tonnes of manure per hectare, if it has not been incorporated into the previous crop, and 90 to 120 units per hectare of nitrogen, phosphorus and potassium. The soil must be well broken up with deep ploughing and a couple of harrowings. In Aragon, staggered sowings are carried out in the open air from mid-August to January, in rows or individual drill holes with 25 to 30 cm between plants.

Cultivation presents no particular problems; the plants must be irrigated and, in the event of intensive cultivation, after thinning out top-dressing must be supplemented by 150 units per hectare of easily assimilated nitrogen.

The vegetative cycle takes between 50 and 120 days and harvesting can begin in mid-October, ending in May since, when high temperatures come with spring, the plant goes into flower and loses its value. Harvesting is done by hand. Each plant has two or three rosettes with five to seven leaves each, with a weight of 500 to 1 000 g per plant.

Production levels of around 60 to 100 tonnes per hectare are obtained. According to data in the Spanish Government's *Anuario de Estadística Agraria*, average yields are 25 tonnes per hectare in the case of open-air irrigation and 36 tonnes per hectare in sheltered cultivation, Navarra being foremost with yields of 40 tonnes per hectare using both methods of cultivation.

Recently, sheltered cultivation under plastic has been gaining in importance. Under these conditions, much longer and fleshier leaf stalks are obtained and the stalk/plant yield rises to 60 percent, as against the 40 percent obtained with open-air cultivation. Production levels are also usually better.

The crop's main enemies are virus diseases (cucumber mosaic virus), soil fungi (*Fusarium* sp.), soil grubs, caterpillars and aphids.

The plant is usually marketed in 15 to 20 kg "bundles", amounting to 15 to 30 clumps, or in 10 to 12 kg boxes as complete plants, with part of the leaf removed. However, the consumer prefers borage to be completely stripped and packed in trays protected with plastic film.

Borage is subject to the technical regulations on the control and certification of horticultural plant seeds. The requirements for seeds of the basic, certified and standard category are 97 percent specific purity, 65 percent germination of pure seeds, with a maximum tolerance of 0.5 percent of seeds of other species. According to INSPV data, in 1989 2 567 kg of borage seed were marketed, 2 489 kg of which were home-grown. Only the white variety was grown.

Another method of cultivation carried out in the Netherlands uses plantlets. After direct sowing, these are allowed to grow to a height of 10 to 15 cm and the complete plantlets are harvested. After washing and root removal, these can be marketed in trays covered with plastic film.

Prospects for improvement

Most improvement work has been carried out using white flower types. Breeding by growers has created forms with more succulent, longer and wider leaf stalks, with little pigmentation and less hair than the wild forms.

One of the main problems of cultivation is its ease of bolting, including the formation of flowers, which lowers the value of production. This process is caused by high temperatures and light intensity and reduced humidity. Breeding for resistance to bolting is a priority improvement objective, and a very high response to breeding is observed.

Although this plant has traditionally been cultivated in the open air, excellent results are now being obtained under plastic, in which case growth improves. A quality product, with long, tender leaf stalks and less hair can be obtained for a good part of the year in a greenhouse. The plant tolerates low winter temperatures and high humidity well. In the area around Zaragoza, borage has been converted into the most profitable crop under plastic.

The expansion of sheltered cultivation may encourage the recovery of this marginalized vegetable. The first tests in this connection have been carried out in Almería. If they prove positive, they would contribute to the diversification of production and to improving the supply in this region, which has great agricultural importance and yet depends on a very small number of crops.

As far as the consumer is concerned, in the case of regions that do not have a tradition of using this plant, borage must be presented stripped and properly packed, so that the work of culinary preparation is reduced. The plant's coarse, hairy appearance may cause some degree of rejection, which is avoided with appropriate cleaning and presentation.

With sights set on possible external markets which are even more demanding than the Spanish market, the high nitrate content of leaves and leaf stalks will need to be reduced. This can be achieved without great difficulty, as breeding to obtain a low nitrate content has been effective in other cases. Breeding to obtain individuals with a low content of lasiocarpine, a pyrrolizidinic alkaloid, would also be advisable, although its content is not excessively high.

As regards the plant's pharmacological use, *in vitro* cultivation of embryos is being developed; this is a technique whereby the active synthesis of linoleic acid takes place. *In vitro* propagation techniques of borage have also been developed.

ALEXANDERS (*Smyrnium olusatrum*)

Botanical name: *Smyrnium olusatrum* L.
Family: Apiaceae = Umbelliferae
Common names. *English:* alexanders, alisander, maceron; *Spanish:* apio caballar, apio equino, apio macedónico, perejil macedónico, esmirnio, olosatro, cañarejo; *Portuguese* and *Galician:* salsa de cavalo, cegudes, apio dos cavalos, rosas de pé de piolho; *Catalan:* api cavallar, abil de siquia, julivert de moro, cugul, aleixandri

Origin of the name

This is the *hipposelinon* of the Greeks, a word which means parsley or "horse celery". In Arabic, during the Andalusian period, it was called *karafs barri*, one of the various *karafs* (celeries) known by Hispano-Arab agronomists, different from cultivated celery (*Apium graveolens*), aquatic celery (*A. nudiflorum*) and mountain or rock celery (the Greek and Latin *petroselinum* or *oreoselinon*). Alexanders has always been identified as oriental or Macedonian, very possibly as a reference to its geographical origin and its allochthonous character.

Properties, uses and cultivation

Its use as a medicinal plant is very old. The Greek botanist Theophrastus (fourth century BC) made reference to the plant. Dioscorides (first century) also included it in his *Materia medica*, commenting that its roots and leaves were edible. According to this author, its seed, taken with wine, is an emmenagogue. However, Galen said that it was less active than celery. In the Córdoba of the caliphs, Maimonides also spoke of its powers. During the Middle Ages, it was constantly considered as a plant with diuretic, depurative and aperient properties, particularly through its root. However, its most outstanding quality was perhaps as an antiscorbutic because of its high vitamin C content. The fruit has carminative and stomachic properties. In the eighteenth century, it continued to maintain its reputation as a medicinal plant, as the *Flore économique des plantes qui croissent aux environs de Paris* described it in 1799.

The plant, and especially the leaves, have a smell and flavour similar to myrrh. Hence the origin of the word *smyrnion*, its generic name. Columela (first century) refers to the plant as "myrrh of Achaea", because it was grown in Greece, which the Romans called Achaica or Achaea. It is also because of its characteristic flavour and smell that it is used as a condiment; it is used to season food in a similar way to parsley, giving flavour to soups and stews, and to prepare sauces accompanying meat and fish. However, its commonest use has been as a fresh vegetable, with a preference being shown for its leaves, young shoots and leaf stalks, which impart a pleasant flavour similar to celery, although somewhat sharper. It has also been eaten cooked. The Latin word *olusatrum*, which means "black vegetable", reflects these uses. The roots were used preserved in a sweet-and-sour pickle. The fruit contains an essential oil, cuminal, which is reminiscent of cumin.

The history of its cultivation is surprising. Of all the Umbelliferae used as vegetables, alexanders has been one of the commonest in gardens for many centuries, although in the nineteenth century it was almost completely forgotten. It was probably being gathered before the Neolithic period and was already being grown as early as the Iron Age. It became very popular during the time of Alexander the Great (fourth century BC) and was widely grown by the Romans, who certainly introduced it into western and central Europe, including the British Isles. It is now naturalized in these regions and on the Iberian Peninsula.

Columela elaborates on its cultivation and methods of consumption: "Before alexanders puts out stems, pull up its root in January or February and, after shaking it gently to remove any soil, place it in vinegar and salt; after 30 days, take it out and peel off its skin; otherwise, place its chopped pith into a new glass container or jar and add juice to it as described below. Take some mint, raisins and a small dry onion and grind them together with toasted wheat and a little honey; when all this is well ground, mix with it two parts of syrup and one of vinegar and put it like this into the aforementioned jar and, after covering it with a lid, place a skin over it; later, when you wish to use it, remove the pieces of root with their own juice and add oil to them."

Isidoro de Sevilla (sixth century [1982]) seems to attach less importance to alexanders.

In France, it was an important vegetable, and was grown on the estates of the Carolingian kings. Thus, in the *Capitular de Villis*, promulgated by Louis the Pious, son of Charlemagne (around AD 795), alexanders appears among the plants which should be cultivated. In the eighteenth century, in Versailles, it was used blanched to accompany winter salads. In the early nineteenth century, Rozier, in his *Dictionnaire universel d'agriculture pratique*, writes: "The leaves of alexanders can appear among cooking condiments, like parsley. Its roots and young shoots are still eaten in England after blanching in the same way as celery."

There is documentation on its cultivation in

Belgium in the fifteenth century and on its abundance in English gardens in the sixteenth century. The Italians also traditionally used this plant. However, by about the eighteenth century its cultivation was only very occasional or had fallen into disuse. In Spain, Font Quer (eighteenth century [1990]) says that its root was eaten in many countries as a salad, raw and cooked, as were the stems and young leaves. By the nineteenth century, Spanish agronomists were no longer making any reference to it. Thus, Boutelou and Boutelou (1801) do not mention it, an omission which contrasts with the 13 pages devoted to celery cultivation.

Alexanders was falling into disuse as from the seventeenth century, in direct competition with the "celery of the Italians", an improved form of wild celery (*Apium graveolens*). This is a case of marginalization in which one plant, doubtless widely used since prehistory, is replaced by another one improved later.

Botanical description

Alexanders is a biennial herbaceous plant with a thick elongated root. The stems grow up to 150 cm and hollow on fruiting. It has large, pinnatisect, basal leaves, with ovate to subrhombic terminal segments; the caulinar leaves are pinnatisect. The umbels have seven to 22 rays, with black, didymous fruit measuring 5.5 to 7.5 × 4 to 7.5 mm. Alexanders flowers from April to June and propagates well from seed. Its chromosome structure is $2n = 2x = 22$.

Ecology and phytogeography

Wild populations of alexanders grow abundantly in salt-marshes and uncultivated land near the sea, normally in lime soils. It is also found in hedges, woods and on waysides.

It is spontaneous throughout southern Europe, North Africa (Algeria) and in the Near East. In former times it was very abundant in the area around Alexandria. Vavilov (1951) places this crop in the Mediterranean gene centre.

It also occurs on the Canary Islands and in the rest of the Macronesian region.

Genetic diversity

Perfoliate alexanders (*Smyrnium perfoliatum* L.) has smaller fruit (3.5 mm long) and is distributed through central and southern Europe and southwest Asia. The blanched stems and leaves are used in salads. Its cultivation is documented in the sixteenth century. According to Mathon (1986), this species is of superior quality.

Nowadays it is very difficult to find cultivars of alexanders. However, several cultivated varieties must have existed. For example, in England in 1570, Petrus Pena and Mathius Lobel wrote: "...the cultivated form is far better than the wild plant...". It seems that the plant is still occasionally grown in Great Britain.

Accessions of this species are kept only in the gene bank of the Córdoba Botanical Garden. They are from wild populations in Andalusia.

Cultivation practices

According to Columela, "alexanders must be grown from seed in ground dug out with a *pastino*, particularly close to walls because it likes shade and thrives on any kind of ground: so once you have sown it, if you do not uproot it fully but leave its stems for seed instead, it lasts forever and requires only light hoeing. It is sown from the feast day of Vulcan (August) until the calends of September, but also in January...".

Nowadays, since cultivation has been relegated to a few family gardens, similar practices are frequently seen. The stem is left to seed, and sowing and spontaneous cultivation takes place. Something like this usually occurs with chard: weeds are removed and a little fertilizer is applied.

Modernization of this crop will depend on techniques similar to those used for celery, including blanching, taking into account the fact that alexanders requires less soil and water.

Prospects for improvement

Celery was also known from antiquity but was considered to be an inedible plant of ill omen. The Greeks, who called it *apion*, used it in funeral ceremonies. It appears to have been grown early in our era by the Latins. Columela refers to it: "...after the ides of May, nothing must be put in the earth when summer approaches, except for celery seed, which must nevertheless be watered, since in this way it does very well...". Paladio also mentions it, probably basing himself on the earlier source. Likewise, in the *Capitular de Villis* (eighth century) reference is made to both *apium* and *olisatum*. Throughout this period, cultivation of alexanders seems to be predominant.

Around the seventeenth century, types of celery appeared which were derived through breeding to obtain a better size and improved succulence of the leaf stalks (var. *dulce* (Mill.) Gaud.-Beaup.) or fuller leaf development (var. *secalinum* Mill.) and which were clearly differentiated from the wild plant. These types are actually different vegetables requiring specific cultivation practices. Thus sweet-leaved celery ("celery of the Italians") is well suited to "blanching", which enables a milder, more tender product to be obtained.

The marginalization or disuse of many vegetables used since ancient times in Europe may be connected with the changing tastes in the Western world. The trend has been away from dishes rich in spices and hot ingredients towards milder dishes, which respect the flavour of the food itself or enhance it. This is perhaps the case with celery *vis-à-vis* alexanders. Alexanders is more bitter and pungent and not as tender as sweet celery.

It is significant in this respect that the last agronomic references to the cultivation of alexanders mention the introduction of the blanching technique. It appears thus in the reports by Versailles and Abbot Rozier: "...after they have been blanched in the same way as celery..."; and Barral and Sagnier, in *Diccionario de agricultura* (1889), write: "...in Turkey the cultivation of this plant is still an honour. The leaf is eaten after it has been blanched...". The blanching technique also used to be employed in North America. It is obvious that the smaller plant, celery, had asserted itself and now served as a reference, making it necessary to adopt the same cultivation practice for alexanders, evidently with little success.

While cultivation of alexanders is waning, cultivation of celery is by contrast on the increase, as is its importance in cool subtropical and tropical areas of Latin America and the Far East. Petiolate cultivars with big leaves are chiefly used.

The recovery of alexanders would be achieved via the derivation of plant materials with a specific typology, for specific uses, and the development of associated agronomic techniques; this seems very unlikely.

SCORZONERA (*Scorzonera hispanica*)

Botanical name: *Scorzonera hispanica* L.
Family: Asteraceae
Common names. *English:* scorzonera, Spanish salsify, black oyster plant, viper's grass; *Spanish:* escorzonera, escorcionera, escurzo, yerba viperina, salsifí negro, salsifí hispánico, churrimana, tetas de vaca; *Catalan:* escurçonera; *Basque:* sendaposei, astobe-harri; *Portuguese* and *Galician:* escorcioneira, escorzoneira

Properties, uses and cultivation

Scorzonera has diuretic and depurative properties. The root has restorative and sudorific properties and is an ingredient of many infusions. It is very rich in carbohydrates (18 to 20 percent in fresh weight), with a high proportion of inulin and laevulin, which makes it very suitable for a diabetic diet. It also contains conopherin (glucoside), asparagine, arginine, histidine and choline.

In upper Aragon, the latex is added to milk as a cure for colds. Its ground, fresh leaves are used against viper bites to soothe the pain. Its peeled root, fresh or cooked, acts as a tonic for the stomach and fortifies the body.

It is considered to be an antidote to the bite of poisonous animals, for which reason in Spanish it is called "escorzonera", i.e. herb against *escuerzo* [toad]. The *Diccionario de la lengua española* of the Real Academia Española mentions that the name derives from the Latin "black root" because of its external colour. In Italian, too, *scorza* means "root" and *nera* "black". However, as documented in Mattioli's *Epistolarium medicinalium libri quinque*, published in 1561, the first interpretation seems correct.

Cultivation of this plant is thought to be recent. No Roman or Arab agronomist mentions it. In Spain, its cultivation is not dealt with either by Andalusian agronomists (tenth to fourteenth centuries) or Castilian writers of treatises in the sixteenth century. The same applies in other countries. In France, it is not mentioned in the *Capitular de Villis* of the Carolingian kings, nor does Olivier de Serves, Henry IV's minister, mention it. It was from the sixteenth century onwards that botanists began to concern themselves with this species, describing it as wild, although sometimes introduced into botanical gardens. It is not quoted as a cultivated plant until up to one century later. In time, it was to become fashionable in several countries. Thus Louis XIV of France was very fond of it.

Although scorzonera was perhaps first cultivated in Spain, its cultivation has never been very important in the country. Boutelou and Boutelou (1801) commented: "Scorzonera is usually sown on the edges of unoccupied beds, the empty spaces being profitably used by this tasty root", thereby demonstrating a marginal rather than a main crop.

On the other hand, it is curious that these same authors visualized a greater agricultural importance for white salsify than scorzonera, contrary to what actually happened. Thus, they thought that "...sometimes the roots of scorzonera can begin to be used the first year after sowing, but they are so thin that there is no point in wasting them so young. They require two or sometimes three years for their root to form. Salsify, which has the same taste and properties and which forms in one year, should be preferred because it requires less time in the ground and its product is much more plentiful." The main improvement activity on this crop has enabled some good cultivars to be obtained, with a greater growth rate and better yields than salsify in annual cultivation.

The part of the plant most used is the tender, fleshy root. It is peeled and then cut into pieces and placed in water with lemon to prevent it from turning black. It can then be eaten in a wide variety of exquisite dishes: raw in a salad; dressed with vinaigrette or with other sauces, steamed and served with Béarnaise or Béchamel sauce or with whole milk cream and toast; sautéed in butter with parsley or other herbs; boiled as an accompaniment for meat; grated with cheese; baked with tomato and roast mutton or pork, fried with oil or butter after being lightly cooked and served with lemon; scrambled with eggs or in omelettes; and preserved in sugar.

It is recommended that, once cooked, the roots should be peeled so that they do not lose their flavour.

The leaves can also be eaten, especially the young ones after boiling. The "beards" – young, fresh and tender leaves – can also be eaten raw.

The young shoots are used in the same way as asparagus.

The flowers are added to salads as a flavouring. They have an aroma reminiscent of cocoa. For this purpose, the flowers of other species such as *S. mollis* and *S. undulata* are also used. The flower buds can be used too. Recipes exist for scorzonera flower omelette.

Botanical description

Scorzonera is a perennial plant with a long, fragile taproot, which is blackish on the outside and white and milky inside, and which increases in size each year. The stems are solitary or few in number, usually branched on the upper part and between 30 and 120 cm long. The leaves are broad, long, fleshy and spatulate. The yellowish flowers are in capitula at the end of the stems. Flowering is in spring and summer (April-June).

Propagation is from seed. The achenes are 10 to 20 mm long, cylindrical, whitish and rough, with a pappus that has several rows of hairs. The weight of 75 to 90 seeds is 1 g, the weight of one litre of them is around 580 g. Under ordinary storage conditions they maintain a high germination capacity for two to three years.

It has a diploid chromosome number: $2n = 14$. In the var. *crispatula*, some polyploids have been detected: $2n = 4x = 28$.

Ecology and phytogeography

Scorzonera grows on dry pasture, rocky areas, in thickets and on limy or marly soils of temperate zones.

It is distributed over central and southern Europe and the south of the CIS, although it is not found in Sicily or Greece or in northwestern Africa or southwest Asia. It probably originates from the Mediterranean region and is native to Spain.

The plant is little cultivated outside Europe. Most cultivation takes place in the gardens of amateurs, with the plant being cultivated in professional gardens on a very small scale. Some estimates put cultivation at only a few dozen hectares. The countries with the biggest cultivated area of scorzonera are Belgium, Poland and members of the CIS.

At present, its cultivation is practically unknown in Spain. Although it is subject to the Technical Regulations on the Control and Certification of Agricultural Seeds and Plants, there is no evidence of the seed being marketed in Spain in recent years.

Genetic diversity

The modern *Scorzonera* genus, which is very close to *Tragopogon*, only includes three sections (*Podospermum*, *Scorzonera* and *Lasiospora*) with some 28 species in Europe. The majority of them are perennial diploid plants with $2n = 2x = 14$. Cytotypes also exist with $2n = 2x = 12$, $x = 6$ being derived from the earlier type through translocation.

In Spain, some 13 species are to be found. The majority of them prefer dry soils. This is the case with *S. angustifolia* L., *S. transtagana* Coutinho, *S. hirsuta* L., *S. crispatula* (Boiss.) Boiss. and *S. brevicaulis* Vahl. *S. parviflora* Jacq. is found predominantly on saline soils; *S. laciniata* L. on alkaline soils; *S. aristata* Ramond ex DC. is calcicolous and is found only in meadows and other grassy places of the Pyrenees, the Alps and Apennines; *S. fistulosa* Brot. del W. in Portugal and southwestern Spain. *S. humilis* L., dwarf scorzonera, grows very widely in Europe, while *S. baetica* (Boiss.) Boiss., *S. albicans* Cosson and *S. reverchonii* Deveaux ex Hervier are found only in southern Spain.

Scorzonera (*S. hispanica* L.) is extremely variable, especially in its leaf shape. The botanical varieties recognized are *crispatula* Boiss. (*S. crispatula* (Boiss.) Boiss.), which is very widespread, and *pinnatifida* (Rouy) Díaz de la

Guardia & Blanca, which is relatively rare; they are basically distinguishable through their leaf morphology.

Numerous commercial cultivars already exist, and there are generally populations with open pollination:

- **Gigante de Rusia**, with a regular cylindrical, very long and smooth root and a very black skin. Various selections derive from it, such as Gigante negra de Rusia, Gigante anual, Annual Giant Bomba, Russisk Kaempe, etc.
- **Lange Jan**, which is of good quality.
- **Elite Stamm**, which is productive, stable, with a high yield of superior size roots.
- **Schwarze Pfahl**, which is similar to Elite Stamm.
- **Pronora**, which has well-formed roots, a smooth skin and, when canned, a good colour and flavour. It is especially suitable for industrial processing.
- **Vulcan, Duplex** and **Pilotis,** which are suitable for the frozen foods industry.
- **Hoffman 83, Flandria, Nero, Duro** and **Habil** are also good cultivars.

There are collections of local races and old cultivars at the Rijksstation voor Plantenveredling de Merelbeke (Belgium), at the Nordic Gene Bank in Alnarp (Sweden) and at the Vavilov Institute of Industrial Plants, St Petersburg.

Cultivation practices

Scorzonera is a vegetable that resists drought well when the plant has already developed.

It has similar cultivation requirements to white salsify. It is a typically winter vegetable which, although perennial, is grown as an annual.

It is usually sown direct in early spring, in shallow furrows, with 25 to 35 cm × 12 to 15 cm spacing. Care must be taken to provide protection from birds, which are very fond of these seeds. About 12 kg of seed per hectare is required. Deep, fresh, loose soil is needed; it must be rich in decomposed organic matter and free from stones or gravel, which cause root deformation. The basal dressing recommended is 30 tonnes per hectare of rotted manure, 50 units of N, 100 units of P_2O_5 and 200 to 250 units of K_2O).

Attention must be paid to the first irrigations and hoeings, which can be controlled chemically, both at pre-emergence and post-emergence, with CIPC. It prefers sunny soils and the presence of easily assimilable nitrogen of which an additional 50 units can be applied as a top-dressing.

Harvesting takes place from November to March and requires perhaps more care than the harvesting of white salsify, since the roots are very fragile. This means furrows of about 40 cm have to be opened parallel to the rows of roots. Storage is good, both on the actual cultivation land and in cold stores at between 0 and -1°C, possibly for two to three months, or frozen, with light industrial processing to clean, peel, cut and scald the vegetables to prevent oxidation.

Yields of around 20 to 30 tonnes per hectare have been obtained.

The most important diseases are mycosis, white rust, oidiopsis and strangulation and splitting of the roots, the aetiology of which is unknown.

Prospects for improvement

Although it is thought that this vegetable is very little cultivated in Spain, because it has not been introduced into Iberian cooking, it should be recognized that serious cultivation problems still exist.

Although scorzonera is more productive than salsify and its cultivation more frequent, the two crops have many problems in common:

- a prolonged cultivation cycle, with garden space being occupied for an excessively long time;

- susceptibility to bolting, even during the first year of cultivation – although this does not hollow the root or impair its quality, it does affect yield, making systematic cuts of the flower stems necessary;
- poor seed storage;
- slow emergence and the need for a constant level of moisture;
- very laborious harvesting, since deep trenches have to be opened because the roots are very long and fragile;
- high nitrate content.

Some of these problems have already been tackled or are on the way to being solved. Thus, Schwarze Pfahl is more resistant to bolting than Elite Stamm.

Einjährige Riesen is particularly resistant to bolting and produces a low percentage of roots with cavities. However, it does not attain the yields of the former. Since genetic variability in respect of the character exists within commercial cultivars, rapid progress in improving this cultivar may be expected.

In Belgium, material is being selected which is especially suited to mechanical sowing and harvesting. Lange Jan, Hoffman 83 and Flandria were the ones which contributed the best product qualities among the cultivars tested.

In Poland, work is being done on the development of cultivars suited to industrial processing (both canning and freezing); some cultivars display a good behaviour in this respect.

Insofar as these improvement objectives are achieved, scorzonera may be expected to begin acquiring greater economic importance. It should not be forgotten that it is a vegetable with a very delicate flavour; its glucide composition is rich in inulin, very unlike other tubers and roots rich in carbohydrates, for instance the potato which has a high starch content. This property may be the reason for the increase in demand and price.

SPOTTED GOLDEN THISTLE (*Scolymus maculatus*)

Botanical name: *Scolymus maculatus* L.
Family: Asteraceae = Compositae
Common names. *English:* spotted golden thistle; *Spanish:* tagarnina, diente de porro; *Portuguese:* escólimo-malhado

Origin of the name and properties

The generic name derives from the Greek, *skolos*, meaning spines, a characteristic shared with many other Compositae. In ancient Greece, a thistle with an edible root was known by the name *skolymos*. Diuretic and antisudorific properties were attributed to these plants.

Spotted golden thistle has occasionally been cultivated, but generally the wild plant has been used, with harvesting being limited to the leaves only in spring. At present, its cultivation is very restricted and is tending to disappear.

Cervantes did not seem to set great store by this plant: "...I do not have a stomach made for spotted golden thistle, nor for *piruétanos*, nor for roots of the forests." However, the fleshy parts of the young leaves, like those of Spanish oyster plant, constitute a delicious vegetable which can be used in soups, stews and scrambled eggs or as an accompaniment for meat. Baked *au gratin*, they make an excellent dish.

Botanical description

Spotted golden thistle is an annual, glabrescent plant with latex. The stems are 20 to 130 cm long, broadly wing-shaped, irregularly dentate and spiny. The leaves, bracts and wings of the stem have a white and continuous cartilaginous edge. The basal leaves are oblong-lanceolate, smooth and pinnatifid, with few spines. The pinnatifid caulinar leaves are sinuate, more or less oval and spiny. The bracts are lanceolate, involucral and are more than five in number. The capitula are golden yellow, solitary or in clusters of two to four and flower from May to June. The achenes are of 3 to 4 mm and without a pappus. The chromosome number is $2n = 2x = 20$.

The plant is propagated from seed. Its behaviour is orthodox in storage and its germination capacity is maintained for a long time. Dormancy phenomena are not very pronounced.

Ecology and phytogeography

Spotted golden thistle is found on uncultivated land, in abandoned fields and ditches and along paths and waysides. It prefers clayey soils and temperate climates.

It is distributed through southern Europe, Southeast Asia, North Africa and the Macronesian region. It is a native plant of the Mediterranean region. In Spain, it grows very widely throughout the country, including the Canary Islands.

It is occasionally cultivated in some areas of the Maghreb, southern Italy and Greece. In Spain, cultivation has practically disappeared.

Genetic diversity

The genus *Scolymus* L. includes another two Mediterranean species with a use similar to that of the spotted golden thistle, the Spanish salsify or Spanish oyster plant (*S. hispanicus* L.), with a wide Mediterranean distribution, and *S. grandiflorus* Desf., with a more restricted distribution in the eastern Mediterranean. These are very close species which differ in the leaf margin and wings of the stem and in the involucral bracts, among other characters. Unlike the spotted golden thistle, these Spanish salsify oyster plants are biennial or perennial.

A great morphological variability is observed, but no collections of material are known.

Cultivation practices

The spotted golden thistle is a very hardy plant which prefers clayey soils, although it grows spontaneously in a wide variety of environments. It tolerates cold and drought.

The method of cultivation is similar to that of Spanish salsify, although the latter thrives better on looser soils. Sowing is direct into the soil ready for cultivation, in late winter, with furrows 30 cm apart. After thinning, the plants are spaced 30 cm apart. It is preferable to apply organic fertilizer beforehand. The usual cultivation practices are very simple, being limited to removing weeds.

With hot temperatures, the plant grows very rapidly, with the basal rosette forming quickly, at which time the leaves have to be harvested.

Prospects for improvement

Spotted golden thistles, like Spanish salsify or oyster plants, are practically unknown vegetables on the market. However, they are appreciated in many Spanish regions on account of their very pleasant flavour. As in the case of so many other crops, its revival will have to be accompanied by a marketing system which creates demand. This means publicity campaigns, utilization standards, recipes for traditional dishes, etc., as well as a product of sufficient quality being available on the markets. The fleshy leaf parts would have to be offered peeled and clean and suitably packaged.

From the point of view of improvement, one of the most serious problems of the spotted golden thistle is the ease with which it goes into flower, encouraged by long-day spring conditions and high temperatures. Selection for resistance to this process would increase the cultivation period and make it possible to improve yields of the basal rosette. The plant's general spininess is another problem.

Undoubtedly, the most urgent task is to carry out collecting expeditions in the Mediterranean basin, including the Maghreb, and to characterize the material collected as a starting point for improvement. At the present time it is already very difficult to find traditional cultigens.

This problem is not limited to the spotted golden thistle and Spanish salsify, or even to the genus *Scolymus*, but affects many other Compositae. For example, the tribe *Carduaceae* contains 80 genera with over 2 650 species, 227 of which are found in Spain and 150 of which are endemic in the country. Many of these plants have agricultural value and have occasionally been cultivated. In the majority of cases, cultivation is on the decline, even though it is being maintained. The recovery of these genetic resources, the characterization of the materials and the initiation of improvement programmes could contribute towards diversification, both of production and supply, thus helping to make Spanish agriculture more competitive.

SPANISH SALSIFY (*Scolymus hispanicus*)

Botanical name: *Scolymus hispanicus* L.

Family: Asteraceae = Compositae

Common names. *English:* Spanish salsify, Spanish oyster plant, common golden thistle; *Spanish:* cardillo, cardillo de comer, cardillo de olla, cardillo bravío, cardo lechar, cardón lechar, cardón lechal, lechocino, cardo zafranero; *Catalan:* cardet, cardelina; *Basque:* kardaberaiakca; *Portuguese:* cardo de ouro, cangarinha

Properties and uses

The Spanish salsify plant has been recognized as having antisudorific and diuretic properties. The Greeks knew it and it is mentioned by Theophrastus. Pliny makes reference to it and considers it an antiperspirant. However, it is barely mentioned by Andalusian agronomists. The translator of an anonymous Hispano-Arab document of the eleventh and twelfth century interprets that *silyan* and *adaliq*, spiny plants which people collect among wild vegetables, are indeed Spanish salsify, *Scolymus hispanicus*.

Although it has been cultivated occasionally, at present it is clearly in recession. Most of the Spanish salsify that is eaten comes simply from collecting the wild plant.

Several parts of the plant have a fairly delicate flavour. The young basal leaves are eaten as a vegetable in salads, boiled, in soups, stews, omelettes, etc. The most pleasant part of the leaf is the central rib, a white fleshy part which is obtained by peeling the leaf, with a scraping movement with one hand from the base to the apex, while the other hand holds the base. The young stems are used in a similar way. Font Quer (1990) mentioned that this plant is appreciated in almost all of Spain's provinces and "...is used widely in stew during the spring". In the sixteenth century in Salamanca, the washed young plants used to be eaten with their root, either raw or in stews with meat. In soup, its roots are prepared with milk, butter and flour.

Botanical description

Spanish salsify is a biennial or perennial plant, which is erect, contains latex and is very spiny. The stems are between 5 and 250 cm long, branched at the top, with discontinuous spiny, dentate wings. The basal leaves are oblong-lanceolate, smooth, pinnatisect, with few spines, and a long petiole. The caulinar leaves are rigid, coriaceous and spiny. The capitula have one to three golden-yellow, enveloping leaves; they are about 3 cm long, in a lateral or terminal arrangement and surrounded by an involucre of spiny bracts. The achenes are 2 to 3 mm with a pappus that has a short corona. It flowers from May to July. The plant is propagated from seed, which has a very good germination capacity for several years and does not exhibit any marked dormancy phenomena. It is a diploid plant: $2n = 2x = 20$.

Ecology and phytogeography

Spanish salsify is found on waste ground and uncultivated land, among rubble, in ditches and along paths; it is most frequently found in sandy places in temperate zones.

Distributed through southern Europe and North Africa, it extends to northwestern France. Vavilov (1951) pinpoints its origin as the Mediterranean region. In Spain, it grows wild in most of the country but shuns high mountains; it is less common in the north. It is also found in the Canary Islands.

It is occasionally cultivated in Mediterranean countries such as Spain, Greece and the Maghreb; it is practically unknown in the United States.

Genetic diversity

There is considerable variability in the morphological characteristics of Spanish salsify such as hairiness, leaf morphology and involucral bracts, receptacular scales, spininess, etc.

No definite cultivars exist; it is still possible to obtain a few cultigens, although there is a serious risk of losing these materials.

There has been no significant activity in collecting or conserving genetic resources of this species.

Cultivation practices

Spanish salsify is a very hardy plant, is resistant to cold and thrives on all kinds of soil, although it prefers light-textured soils that are rich in organic matter. Its cultivation requires very little care.

Sowing is direct and is carried out in late winter or in spring. A light, well-drained, manured soil should be used. It can be sown in furrows, 30 cm apart with a distance of 30 cm between plants after thinning.

The young white shoots can be pulled up when they reach 20 cm or so in height. The fleshy parts of the leaves need the basal rosette to be well formed. The roots are usually harvested around the end of October or during the winter. If the plant is left until the following year, it goes into flower and develops a sturdy stem, while the basal leaves lose their quality because of toughening. Therefore, although the plant can be kept for several years, it should be cultivated as an annual.

There are no serious phytopathological problems.

Prospects for improvement

The considerably spiny nature of the Spanish salsify plant, and especially of the caulinar leaves which have big, tough spines, is a serious drawback to its handling and deters attempts to cultivate it. The breeding of less spiny forms would facilitate the plant's handling.

As far as the most widely used portion is concerned – i.e. the fleshy part of the leaves – forms will need to be bred that have thick, tender and juicy ribs. Wide collections of material must be made, especially of the old cultigens which can still be recovered, so as to characterize and select them. The areas of greatest interest are the Maghreb, southern Greece and non-horticultural Spanish regions.

If the intention is to use the roots, harvesting should be carried out until the end of the winter. Resistance to flowering will enable root yield to be improved by encouraging rapid root growth at the time of hot weather.

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The latter section reflects the intention to study possible reciprocal moves in the exchange of flora and crops, begun in 1492, between the two sides of the Atlantic.

Thus, in addition to being thought-provoking and useful for the conservation and improvement of the crops dealt with, the book offers very different views from those conventionally established for examining the repercussions of the discovery of America.

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