Effects of Corona Discharge on the Germination Characteristics of Wild Pea Seeds in High Altitude Alpine Meadow

Fubao Jin[1,a,*], Jinqiang Shi[1,b,*], Shangang Ma[1,c], Jiuxiang Xie[2,d] and Ning Xin[1,e]
[1]College of Water Resources and Electric Power, Qinghai University, Xining 810016, China
[2]College of Agriculture and Animal Husbandry, Qinghai University, Xining 810016, China

Keywords: Electricity To Faint From Stress, Wild Pea Seeds, Electric Field Biological Characteristics, Germination Rate, Germination Potential.

Abstract: The natural environment in the high-altitude areas of Qinghai Province is harsh, and the ecology of its alpine meadows is seriously degraded. To improve the seeds and increase their germination rate, this paper took the wild pea seeds widely distributed in high altitude and cold areas as the research object, built an experimental platform for the biological characteristics of the electric field, and used a multi-needle circular electrode corona field generator to pretreat the wild pea seeds. Explore the effects of corona electric field, temperature, and humidity on the germination characteristics of wild pea seeds. By constructing a multi-needle circular electrode corona model and simulating the internal electric field distribution, the analysis showed that the spatial corona electric field had a consistent effect on wild pea seeds. The results of the study showed that under the conditions of a temperature of 20 °C and a humidity of 40%, changes in the electric field had two characteristics: promoting and inhibiting the germination of seed. The electric field generated by the applied voltage of 15 kV promoted the germination of wild pea seeds. That helped break the shells of wild pea seeds and increases their germination rate. While the electric field generated by the applied voltage of 9 kV had the opposite effect. Seeds treated with an electric field generated by an externally applied voltage of 15 kV for 30 min, under the same humidity and different temperature conditions, had the highest germination potential and germination rate at 25 °C, and the lowest germination potential and germination rate at 15 °C. Under different humidity conditions of 20 °C, the seeds treated with the same electric field had the highest germination potential and germination rate at the humidity of 60%, and the lowest germination potential and germination rate at a humidity of 95%. Through the research of this paper, the germination rate of alpine wild pea was improved, so as to make efforts for low-carbon agricultural ecological protection in Qinghai, China and the world.

1 INTRODUCTION

Qinghai Province is located in the high-altitude area of the Qinghai-Tibet Plateau in my country. Due to harsh natural environment factors such as high terrain, low temperature, and strong sunlight, the adaptability of alpine meadows to low temperature has become weak, resulting in low seed germination rates and even degradation.

At present, there are relatively few studies on the seed germination behavior of alpine meadow plants in high altitude areas, mainly from the conventional methods of temperature, humidity and light to explore the growth law of meadow seeds (XU, 2014); (WANG, 2018); (CAO, 2018); (XU, DU, LI, 2013); (MA, 2008). High-voltage corona field is an important means to generate low-temperature plasma, and it is also an important method for seed treatment under the development of new agricultural technology. The mechanism of this physical mutagenesis technology is still unclear, but its mutagenic effect is remarkable. Studies have shown that the action of electric field promotes seed germination and has the characteristics of enhancing stress resistance (LING, JIANGANG, MINCHONG , 2016); (XU, SONG, LUAN, 2019); (JIAFENG, XIN, LING, 2014). Different types of electric field treatment seeds also have a promoting effect, such as high-voltage DC electrostatic field, AC high-voltage pin-plate corona field and high-voltage pulsed electric field (WANG, 2020); (LUAN, SONG, DU, 2019). Temperature and humidity as growth factors

Jin, F., Shi, J., Ma, S., Xie, J. and Xin, N.
Effects of Corona Discharge on the Germination Characteristics of Wild Pea Seeds in High Altitude Alpine Meadow.
DOI: 10.5220/0011193800003443
In *Proceedings of the 4th International Conference on Biomedical Engineering and Bioinformatics (ICBEB 2022)*, pages 175-183
ISBN: 978-989-758-595-1

for seeds. Due to their own physiological characteristics, there are differences in the optimal germination temperature range for different seeds (ZHAO, 2020); (YANG, DU, SHI, 2020). The humidity aspect mainly focuses on the moisture in the soil, or soaking and absorbing the seeds to meet their demand for moisture (NOVIKOV, NOVIKOV, ERMOLAEVA, 2015).

This paper takes the wild pea meadow seeds widely distributed in Qinghai as the research object. The seeds have a certain hard phenomenon and are difficult to imbibe and germinate. In addition, the harsh environmental factors in Qinghai also affected the germination and growth of wild pea seeds. And the current methods to improve the germination of wild pea seeds are mostly mechanical breaking, temperature adjustment and chemical reagent treatment (WANG, WANG, CHAO, 2015); (LI, 2013); (YUAN, ZHANG, YUAN, 2018); (CHEN, NA, WANG, 2017). There are few studies on the use of electric field as a pretreatment condition to break the hard seed of wild pea seeds. Therefore, the study of corona discharge to solve the problem of hard seed in the wild pea meadow seeds is beneficial to improve its germination rate, thereby solving the local meadow agro-ecological problem in Qinghai.

2 MATERIALS AND METHODS

2.1 Materials

The test material is wild pea seeds.

2.2 Construction of Test Platform

The test uses the device shown in Fig.1, which is mainly composed of an AC test transformer T (10kVA/100kV), a power frequency protection resistor R (5kΩ), a coupling capacitor divider C (500pF), and a high-voltage corona electric field device. Connect and debug the electric field biological characteristics experimental platform, so that the seeds are processed by the high-voltage corona electric field device through the circuit.

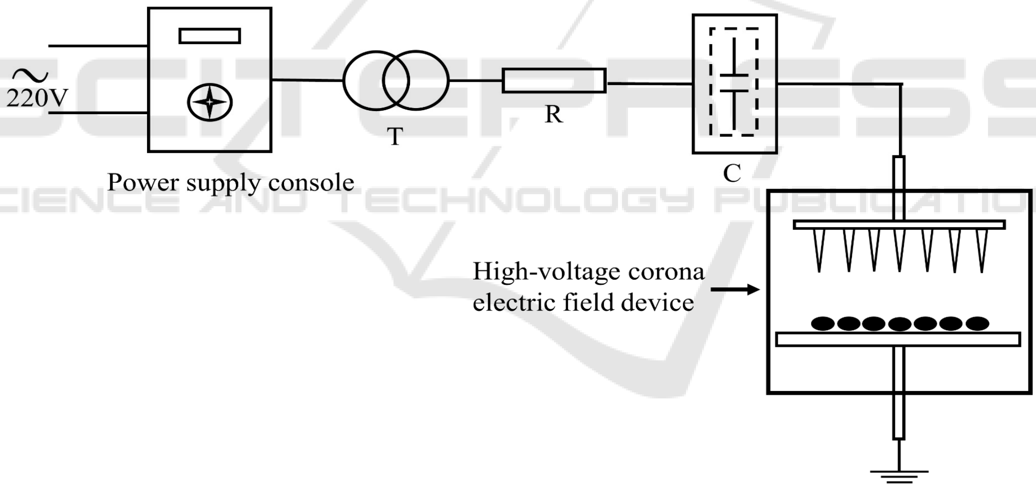
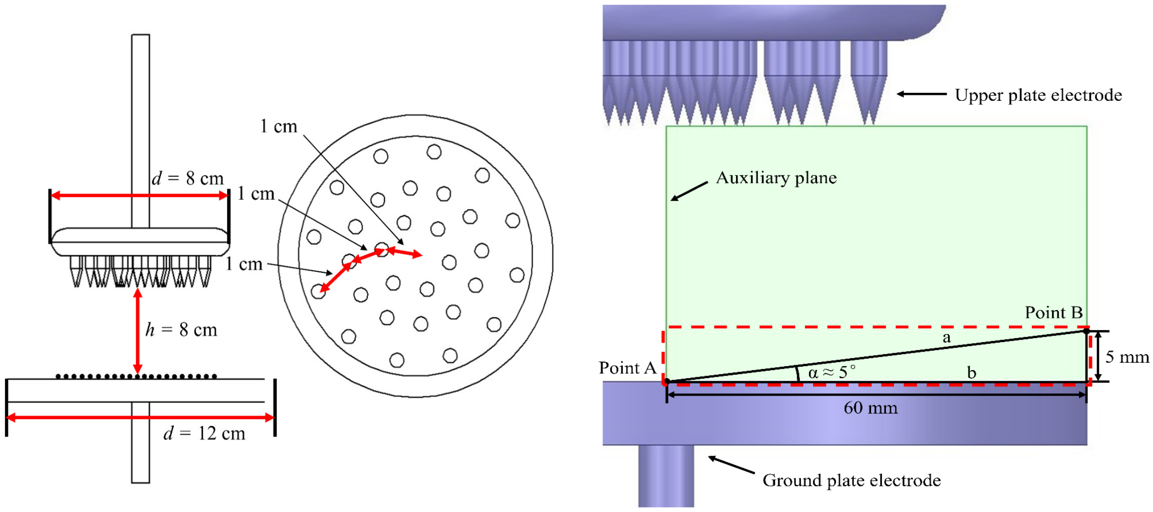


Figure 1: Schematic diagram of electric field biological experiment platform.

2.3 Consistency Analysis of Seeds Affected by Corona Field

The multi-needle circular electrode is an important device for treating seeds, which generates corona by applying AC voltage. In this paper, a three-dimensional model of the high-voltage corona device is established and electric field simulation is carried out. By simulating the electric field distribution characteristics of the electrode space under the action of a high-voltage AC power supply, the consistency of the electric field on wild pea seeds is analyzed.

As shown in Fig.2(a), the high-voltage corona electric field device is designed in a 1:1 ratio according to the actual size, which is respectively the upper plate electrode and the ground plate electrode. The corona discharge it can produce is a self-sustaining discharge phenomenon unique to extremely inhomogeneous electric fields.



(a) Corona electric field device (b) Simulation assistance

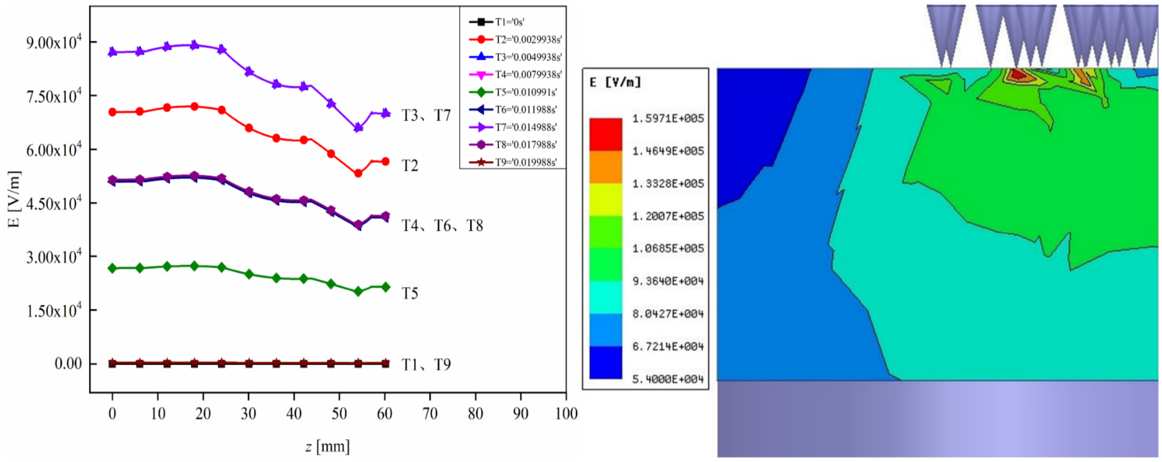
Figure 2: Corona electric field device and Simulation assistance.

Due to the complexity of the time-varying electric field and the actual simulation results, this paper selects 9-time nodes that are relatively uniform in the power frequency cycle for electric field analysis. Due to the circular symmetry of the needle-plate electrode, to simplify the analysis and to take into account the volumetric diameter of the wild pea seeds, an auxiliary plane was chosen to be constructed as shown in Fig.2(b) to analyze the electric field intensity distribution cloud diagram at the peak time of 0.0049938s, as well as the electric field intensity on the auxiliary straight line based on nine-time nodes, is analyzed. In Fig.2(b), the auxiliary straight line a is positive from point A to point B, and the parameter z is used to represent the distance change from point A to point B. The reference to the volume diameter of wild pea seeds of 5 mm makes the height of point B from the ground plate electrode 5 mm. Since the small-angle α is about 5°, side a and side b can be approximately equivalent. At the same time, the electric field intensity on the straight-line a and the straight-line b are also approximately equivalent accordingly. Finally, the electric field intensity distribution on the straight line a is equivalent to the intensity of the electric field in the rectangular box further characterizing the range of actual wild pea seeds being affected by the electric field.

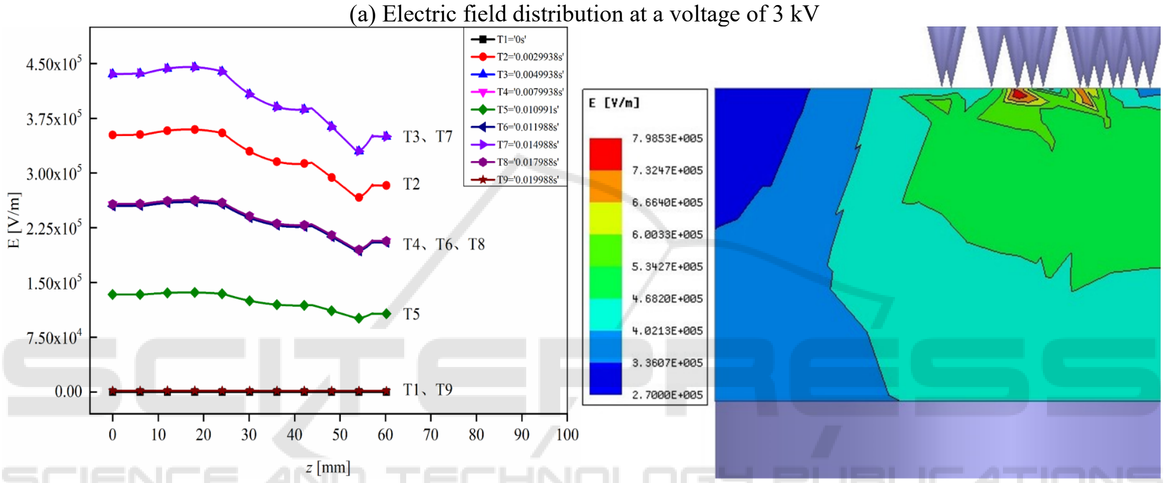
The simulation results at voltage values (3kV and 15kV) are shown in Fig.3. By analyzing the above-mentioned electric field intensity distribution cloud diagram at different voltages when the peak time is 0.0049938 s, it can be qualitatively observed that nearly half of the space above the ground plate electrode has the characteristics of uniform electric field distribution. Since the AC voltage fluctuates with time, and by observing the above electric field intensity curves, it is found that the electric field intensity tends to be roughly the same at each time.

As shown in Tab.1, the range of the drastic change of the electric field intensity is about 22.5~27.5mm. The corresponding difference between the maximum and minimum values are respectively 0.02193 kV/cm, 0.04388 kV/cm, 0.06581 kV/cm, 0.08774 kV/cm, and 0.10968 kV/cm, which shows that the maximum difference in electric field intensity is about 0.1 kV/cm and the smaller values have less influence on the results of the experiment. The average electric field strengths at each voltage are respectively 0.880 kV/cm, 1.760 kV/cm, 2.640 kV/cm, 3.520 kV/cm and 4.400 kV/cm.

Therefore, the range of electric field acting seeds can be set to a cylindrical space with a radius of 25 mm and a height of 5 mm.



(a) Electric field distribution at a voltage of 3 kV



(b) Electric field distribution at a voltage of 15 kV

Figure 3: The electric field distribution between the needle-plate electrodes at five voltage levels.

Table 1: Electric field intensity on the auxiliary line.

z[mm]	3kV[V/m]	6kV[V/m]	9kV[V/m]	12kV[V/m]	15kV[V/m]
0	87131	174262	261393	348523	435654
2.53	87177	174353	261530	348706	435883
5.06	87264	174528	261792	349056	436320
7.53	87454	174909	262363	349817	437272
10.05	88202	176405	264607	352809	441012
12.52	88721	177442	266163	354884	443605
15.05	89014	178028	267041	356055	445069

Refer to Tab.1 (continued)

z[mm]	3kV[V/m]	6kV[V/m]	9kV[V/m]	12kV[V/m]	15kV[V/m]
17.52	89049	178099	267148	356197	445246
20.05	88815	177629	266444	355258	444073
22.52	88310	176621	264931	353242	441552
25.05	86856	173711	260567	347423	434278

2.4 Test Methods for Seed Germination Characteristics

2.4.1 Corona Field Treatment and Cultivation

Before the experiment, wild pea seeds with a uniform particle size were laid on the bottom plate according to the specifications with a radius of 25 mm and a height of 5 mm. Each electric field treatment 150 wild pea seeds, and the test voltage is 3 kV, 6 kV, 9 kV, 12 kV, and 15 kV. The treatment time was 30 minutes, and the control group was not treated (only treated by the electric field, and its temperature and humidity were not controlled). Each group of experiments was repeated three times. After the experiment, 150 wild pea seeds were divided into three petri dishes with a diameter of 9 cm and three layers of filter paper on the bottom. The control and experimental groups were placed in the same intelligent artificial climate box The wild pea seeds were cultivated continuously for 8 days at a constant temperature of 20 ℃, a constant humidity of 40%, with sunlight and dark time of 12 hours respectively, with a sunlight intensity of 1200 LX and without placing a lid of a petri dish. Wild pea seeds treated with an electric field generated by an externally applied voltage of 15 kV for 30 minutes were placed in constant humidity (RH 40%) and different temperatures (15 ℃, 20 ℃, 25 ℃, 30 ℃), and the same temperature (20 ℃) and different humidity (40%, 60%, 80%, 95%) environment for cultivation. The statistics of the wild pea growth process began on the 4th day and counted to the 8th day. The data of repeated tests are finally averaged.

2.4.2 The Calculation Method of the Germination Index of Wild Pea Seeds

$$\text{Germination potential (\%)} = \frac{A_4}{A} \times 100\% \qquad (1)$$

Where A_4 denotes the number of the germination on the fourth day and A represents the number of experimental seeds of 50.

$$\text{Germination rate (\%)} = \frac{A_x}{A} \times 100\% \qquad (2)$$

Where A_x denotes the number of the germination, x represents the number of days and A represents the number of experimental seeds of 50.

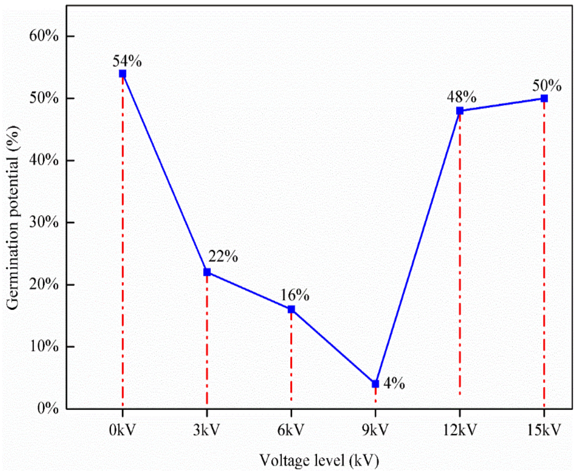
3 EXPERIMENTAL RESULTS AND DISCUSSION

3.1 Effect of Corona Electric Field on the Germination of Wild Pea Seeds

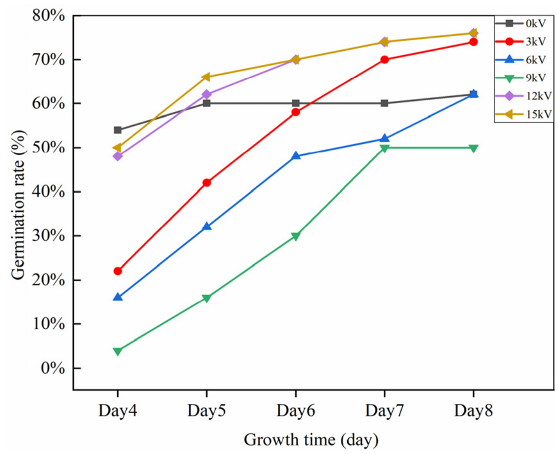
The germination potential of wild pea seeds after treatment with different voltages in the corona field is shown in Fig.4.

As shown in Fig.4(a), the germination potential of wild pea seeds was all inhibited after the action of the electric field, showing a trend of decreasing and then increasing with increasing voltage. The results show that in the electric field from 0 kV (0 kV/cm) to 9 kV (2.640 kV/cm), the increase in voltage (electric field strength) will gradually strengthen the growth inhibition of wild pea seeds. The effect was that the strongest inhibition at 9 kV where the germination potential was 4%, while the increase of electric field from 9 kV to 15 kV made the inhibition of wild pea growth weaker. This indicated that the difference in the magnitude of voltage (electric field strength) leads to different degrees of growth inhibition and the electric field has different effects on the activities of the correlated enzyme inside wild pea seeds.

As shown in Fig.4(b), the germination rate was increasing with an increasing number of days at the same voltage. The specific analysis resulted in the following three points.



(a) The germination potential of wild peas



(b) The germination rate of wild peas

Figure 4: The germination of wild peas.

(1) The germination rate of wild peas in the control group (without electric field treatment) was about 60%, and the germination rate of wild pea seeds at 6 kV (1.760 kV/cm) and 9 kV (2.640 kV/cm) was significantly lower than that of the control group from the 4th day to the 7th day. Although the germination rate of both the electric field of 6 kV and the control group was 62% on the 8th day, the overall showed an inhibition of the growth of wild pea seeds by the action of electric fields at both 6 kV and 9 kV. And the inhibition was more pronounced at 9 kV, with the germination rate of 50%, which was 10% lower than the control group. This shows that the electric field at 9 kV (2.640 kV/cm) causes a severe inhibition towards the germination potential of wild pea seeds. Due to the complexity of the biological effects, an electric field at 9 kV (2.640 kV/cm) reduces the activity of the relevant enzymes inside the wild pea seeds, which is detrimental to growth.

(2) Although the germination rates at 12 kV (3.520 kV/cm) and 15 kV (4.400 kV/cm) were lower than the control group on the 4th day, they were higher than the control group on subsequent days. Since the germination rates were the same on the 6th, 7th, and 8th day and were higher at 15 kV than at 12 kV on both the 4th and 5th day. Although both fields promoted the growth of wild peas, the 15 kV field had a better effect, with a germination rate of 76%, which was about 27% higher than the control group. Therefore, the electric field of 15 kV was effective in promoting the enzyme activity and growth vigor of wild pea seeds.

(3) During the germination process, different voltage magnitudes can cause differences in wild peas in the time to change from inhibition to promotion by the electric field. On the 4th day, the germination of wild pea seeds was all inhibited by the electric field compared to the control group. Compared to the growth on the 4th day, the change from inhibition to the promotion of germination by electric field treatment of 12 kV and 15 kV was only 1 day (on the 5th day). Their germination was higher than that of the control group and more pronounced at an electric field of 15 kV. The germination at the electric field of 3 kV was higher than the control group after 3 days (on the 7th day), while the germination at the electric field of 6 kV was the same as the control group on the 8th day. The germination at the electric field of 9 kV was continuously inhibited from day 4 to day 8 and was lower than that of the control group. This shows that the difference in electric field shortens the time to change from inhibition to promotion by the electric field in the growth of wild pea, with the shortest transition time and most effective promotion at 15 kV (4.400 kV/cm) and continued inhibition at 9 kV (2.640 kV/cm).

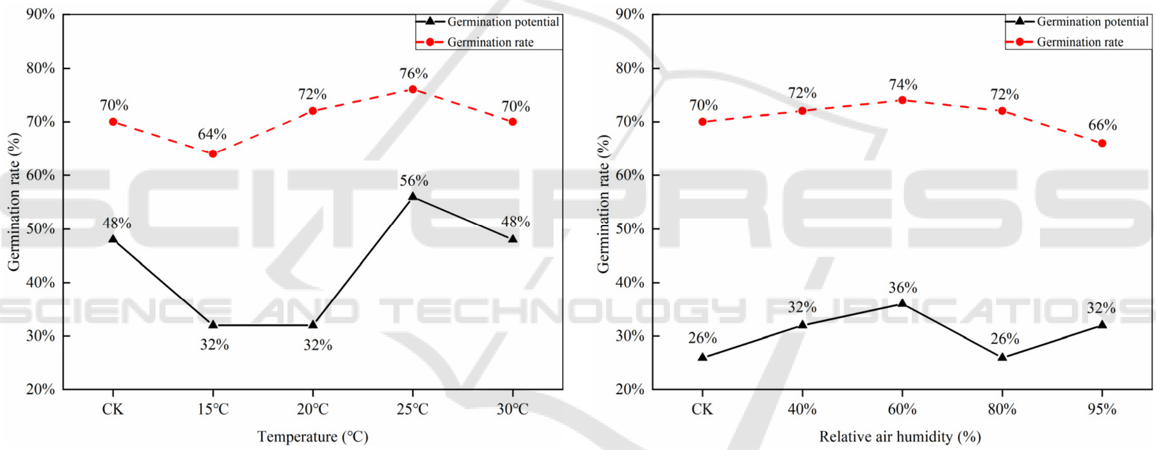
3.2 Effect of Temperature and Humidity on Germination of Wild Pea Seeds after Electric Field Treatment

Wild pea seeds treated with an electric field of 15 kV (4.400 kV/cm) for 30 min were placed at room temperature (CK) and relative air humidity of 40% a temperature of 20 ℃ with different temperatures of 15 ℃, 20 ℃, 25 ℃, and 30 ℃. Wild pea seeds treated with an electric field of 15 kV (4.400 kV/cm) for 30 min were placed at room temperature (CK) and a temperature of 20 ℃ with the different relative air humidity of 40%, 60%, 80%, and 95%. The specific growth dates are shown in Fig.5(a) and Fig.5(b), respectively.

3.2.1 Effect of Temperature on Germination of Wild Pea Seeds after Electric Field Treatment

The germination potential and germination rate of wild pea seeds when incubated showed a tendency to increase and then decrease with the increase of temperature at 15 ℃, 20 ℃, 25 ℃, and 30 ℃. The highest seed germination rate of 76% was achieved at 25 ℃, which was 6% higher than the control group (which was only treated with an electric field without controlling its temperature and allowed to grow under natural conditions). And the highest germination potential of 56% was also achieved for wild pea seeds at this temperature, which was 8% higher than the control group.

When the temperature increased to 30 ℃, although the germination potential of the seeds was higher, the germination rate was lower than at 20 ℃ and 25 ℃. This shows that high-temperature conditions for a short period can promote the internal physiological response of seeds and improve seed vigor, but there is an inhibitory effect leading to a decrease in seed vigor when exposed to high temperature for a long period. The germination potential of 32% of seeds at both 15 ℃ and 20 ℃ was lower than that of 48% in the control group, but the germination rate of 72% at 20 ℃ was higher than both the germination rate at 15 ℃ and the germination rate of 70% under the control group. At the same time, the germination potential and germination rate of seeds cultivated at 15 ℃ were lower than those of the other groups, which indicated that low temperature inhibited the activity of seeds, resulting in a decrease in the germination rate of seeds.



(a) The germination of wild peas at different temperatures (b) The germination of wild peas under different humidity

Figure 5: The germination of wild peas at different temperatures and humidity.

3.2.2 Effect of Humidity on Germination of Wild Pea Seeds after Electric Field Treatment

The germination potential showed a trend of increasing, then decreasing, and finally increasing again in the selected humidity range. The germination potential of 36% at the relative humidity of 60% was the highest, which was 10% higher than the 26% of the control group. The germination potential of wild pea seeds showed a trend of increasing and then decreasing with increasing air humidity. And as predicted by the germination potential, the highest germination rate of 74% at the relative humidity of 60% was more suitable for the growth of wild pea seeds.

Humidity will change the growth hormones inside the seeds, as well as the activity of related enzymes inside the seeds, and the increased concentration of growth hormone will also help to promote seed germination. As shown in Fig.5(b), the germination potential and germination rate of wild pea seeds under different humidity conditions were higher than those of the control group. Compared to the germination rate of about 60% without electric field treatment (WANG, LIANG, WU, 2017), the germination rate did not differ much and both increased by about 10% within the relative air humidity range of 40% to 80%, and the highest germination potential of 36% and germination rate of

74% at a relative humidity of 60%. This shows that the increase in air humidity does promote the germination of wild pea seeds, breaks the dormancy, and reduces the hardening rate.

Proper air humidity can provide a better growing environment for seed germination, soften the seeds for water uptake, thereby increasing the activity of relevant enzymes inside the seeds and promoting germination. However, too high humidity will cause seeds to become moldy and inhibit the internal respiration of the seeds, while too low humidity can make it difficult for seeds to absorb water and germinate. The relative humidity of 95% certainly promotes germination of wild pea seeds, but excessive air humidity compared to 60% and 80% will cause wild peas to mold, resulting in reduced germination rates. Therefore, the relative air humidity of 95% inhibited wild pea seeds germination most significantly.

4 CONCLUSION

In this paper, corona field was used to treat wild pea seeds in the high-altitude alpine meadow. Through the study of its biological characteristics, the conclusions are as follows:

(1) Different voltage (electric field strength) magnitudes both promoted and inhibited seed germination. The electric field of 15 kV (4.400 kV/cm) helped wild peas seeds to break their shells and promote germination, with germination potential and germination rate of 50% and 76%, respectively. In contrast, the electric field at 9 kV (2.640 kV/cm) inhibited germination, with germination potential and germination rate of 4% and 50%, respectively.

(2) Wild pea seeds treated with an electric field of 15 kV (4.400 kV/cm) for 30 min are best suited for germination at a relative air humidity of 40% and a temperature of 25 °C, with germination potential and germination rate of 56% and 76%, respectively. The optimum relative air humidity for germination of wild pea seeds treated with the same electric field at a temperature of 20 °C was 60%, and the germination potential and germination rate are 36% and 74%, respectively.

(3) The difference in the electric field during germination shortens the time for the effect of electric field on wild peas from inhibition to promotion. During the germination period from the 4th day to the 8th day, the shortest transition time and most effective promotion were observed in the electric field of 15 kV (4.400 kV/cm), and the inhibitory effect persisted in the electric field of 9 kV (2.640kV/cm).

ACKNOWLEDGMENTS

This work is supported by The Open Project of State Key Laboratory of Plateau Ecology and Agriculture, Qinghai University (No. 2019-ZZ-13).

REFERENCES

CAO Suzhen. Study on the response of common plants to temperature increase in alpine meadow of Qinghai-Tibet Plateau [D]. Animal Science ·Pratacultural science Lanzhou University, 2018. (DOI:https://doi.org/CNKI:CDMD:1.1018.829383).

CHEN Yishi, NA likesi Waili, WANG Shulin, et al. Effects of different treatments on seed dormancy and seedling development characteristics of legume [J]. Acta Agrestia Sinica, 2017,25(04) : 823-831 (DOI:https://doi.org/CNKI:SUN:CDXU.0.2017-04-020).

JIAFENG J, XIN H, LING L, et al. Effect of Cold Plasma Treatment on Seed Germination and Growth of Wheat[J]. Plasma Science and Technology, 2014,16(1). (DOI:https://doi.org/10.1088/1009-0630/16/1/12).

LING L, JIANGANG L, MINCHONG S, et al. Improving Seed Germination and Peanut Yields by Cold Plasma Treatment [J]. Plasma Science and Technology, 2016,18(10). (DOI:https://doi.org/10.1088/1009-0630/18/10/10).

LUAN Xinyu, SONG Zhiqing, DU Jiaxin, et al. Effects of high voltage corona field on the treatment of alfalfa [J]. Seed, 2019,38 (09) : 18-23. (DOI:https://doi.org/10.16590/j.cnki.1001-4705.2019.09.018).

LI Tingshan. Studies on the characteristics of seed dormancy and germination of Vicia narrow-leafed [D]. Lanzhou University, 2013.

MA Xiaojuan. Study on the mechanism of seed germination and seedling establishment in alpine meadow [D]. Lanzhou University, 2008. (DOI:https://doi.org/10.7666/d.Y1332523).

NOVIKOV S N, NOVIKOV L N, ERMOLAEVA A I, et al. Changes in Properties of Water during Germination of Zucchini Seed in Water Used[J]. Biofizika, 2015,60(4): 816.

WANG Lipei. Study on the response of soil seed bank to temperature increase and rainfall change in alpine meadow of Qinghai-Tibet Plateau [D]. Lanzhou University, 2018. (DOI:https://doi.org/CNKI:CDMD:2.1018.979824).

WANG Zihan. The prince. Experimental Study on Germination of Soybean Seed Based on High Voltage DC Electrostatic Field Regulation [J]. Modern

Agricultural Science and Technology, 2020(07) : 226-227. (DOI:https://doi.org/CNKI:SUN:ANHE.0.2020-07-137).

WANG Dan, WANG Junjie, CHAO Ketu, et al. Studies on seed dormancy and germination characteristics of Vicia occidentalis [J]. Seed, 2015,34(07): 8-11. (DOI:https://doi.org/10.16590/J.cnki.1001-4705.2015.07.008).

WANG Chuanqi, LIANG Sha, Wu Junxi, et al. The effect of temperature on the seed germination of 5 wild legumes in Tibet[J]. Seeds, 2017,36(10): 1-5, 11. (DOI:https://doi.org/10.16590/j.cnki.1001-4705.2017.10.001).

XU Jing Seed germination behavior of alpine meadow plants and its response to environmental factors in the eastern margin of the Qinghai-Tibet Plateau [D]. Lanzhou University, 2014.

XU Jing, DU Guozhen, LI Wenlong, et al. Effects of temperature and altitude on seed germination and evolution of alpine meadow [J]. Journal of Lanzhou University (Natural Science Edition), 2013,49 (03) : 377-383. (DOI:https://doi.org/10.13885/j.issn.0455-2059.2013.03.016).

XU W, SONG Z, LUAN X, et al. Biological Effects of High-Voltage Electric Field Treatment of Naked Oat Seeds[J]. Applied Sciences, 2019,9(18). (DOI:https://doi.org/10.3390/app9183829).

YANG Yanting, DU Baohong, SHI Fengling. Effects of different temperature treatments on seed germination of Medicago ruthenica [J]. Seed, 2020,39(12) : 85-88. (DOI:https://doi.org/10.16590/j.cnki.1001-4705.2020.12.085).

YUAN Xue, ZHANG Yan, YUAN Tao, et al. Study on the propagation technology of wild fire ball and vetch [J]. Seed, 2018,37 (09) : 96-99. (DOI:https://doi.org/10.16590/j.cnki.1001-4705.2018.09.096).

ZHAO Mingwei. Effects of different temperature, light quality and light duration on growth and quality of frozen cabbage [D]. Shihezi University, 2020. (DOI:https://doi.org/10.27332/d.cnki.gshzu.2020.000680).