WESTERN LABORATORIES
Your Potato and Onion Specialists Since 1973

The Fate of Ammonium and Potassium In Saline Soils

% TBS (Taberna Base Saturation) for Soils with pH >7.0

What is % Base Saturation and why is it such an issue now?
% Base Saturation is calculated from CEC. I am going to differentiate between the Taberna Base Saturation, which is based on measured CEC and the Bear/Albrecht sum of the cation Base Saturation. By definition CEC is the measurement of the negative sites of clay and humus. Most labs do not actually measure the CEC. They add the amount of meq. Calcium (Ca^{++}) + meq. Magnesium (Mg^{++}) +meq. Potassium (K^{+}) + *meq. Sodium* (Na^{+}) *and that equals their CEC. It is the sum of the cation* but not measured CEC. Then, they use a factor for Hydrogen H^{+} of 1.25-1.50 for each 1/10th pH below 7. For example: if the pH is 6 the % H from these labs would be 12.5% to 15% using these factors. If the soil had 15% Hydrogen then it would be 85% Base Saturation of Ca + Mg + K + Na. Albrecht and his coworkers were the first to popularize the sum of the cations. It still works on pH 5.0 to 7.0. This is why we are introducing % TBS (Taberna Base Saturation).
In the early 1940's, Dr. F. Bear from Rutgers University developed the "ideal balance" for crops in acid soil. The results were then used to establish a balance on soils in alfalfa. Later, Dr. Albrecht at the University of Missouri took these numbers and applied them to midwestern soils. (Figure1)

Bear/Albrecht

Percent Base Saturation		
BASES	IDEAL	YOURS
Calcium % of CEC	65-80	
Magnesium % of CEC	10-20	
Potassium % of CEC	2-6	
Sodium % of CEC	<5	
Hydrogen % of CEC	<15	

Figure 1

The Problem with most Labs

Most labs are calculating base saturation by the sum of the cations method on soils with pH greater than 7. This works in acid soils unless there is a problem such as going from a soil planted in blueberries for forty year to sweet corn. Yet, you have "experts" thinking that they can come to the alkaline west and balance soils according to the Albrecht philosophy.

1957 Yearbook of Agriculture

In the 1957 Yearbook of Agriculture, Coleman and Mehlich stated that neutral soils are base saturated and acid soils containing exchangeable H+ and Al+++ are base unsaturated. (Figure 2 pg. 72-79)

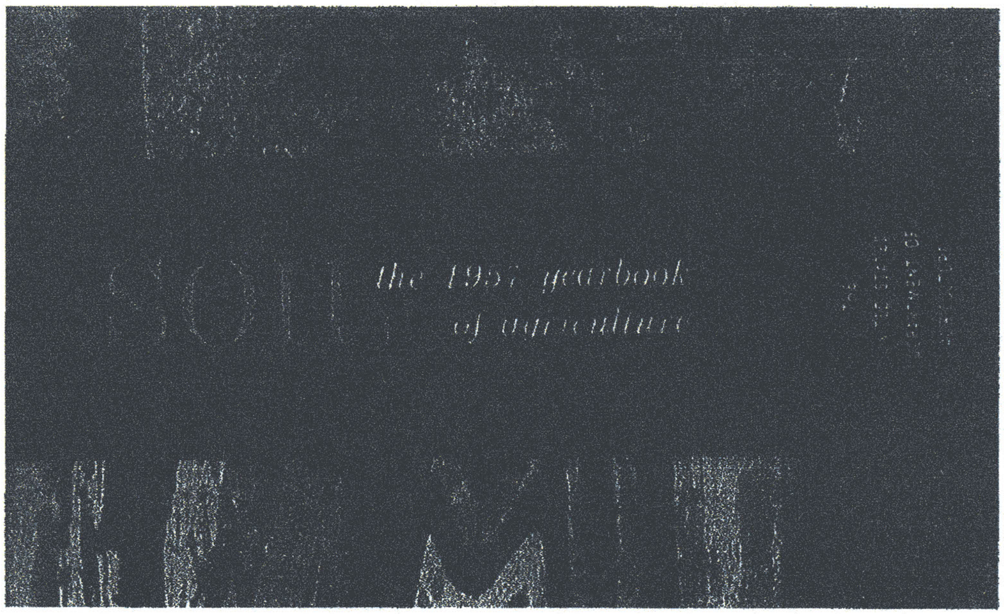

Figure 2

It would be my guess that most soil experts have not read this book. What they are stating is that a neutral soil has pH 7.0 and $Ca^{++} + Mg^{++} + K^{+} + Na^{+}$ occupy all exchange sites on clays and humus; therefore the base saturation is 100%. I created this chart in 1969 (Figure 3) to give a better understanding of how pH and base saturation work hand in hand.

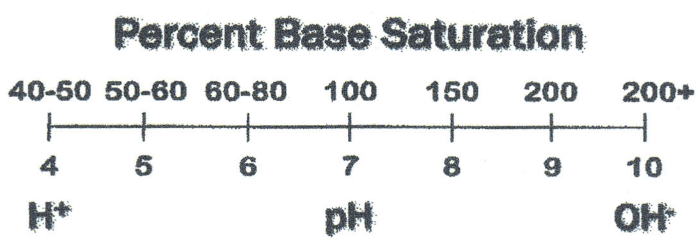

Figure 3

A base unsaturated soil has a pH less than 7.0 and possesses exchangeable H^+. If you refer back to Figure 1, you will see that Bear and Albrecht had Hydrogen (H^+) in their base saturation because they were dealing with acid soils. When Ca^{++} and Mg^{++} are added to acid soils, they replace hydrogen (H^+) from the clay and humus, which increases pH towards 7 and base saturation toward 100%. This is the technique many companies in the East and the Midwest use to balance the soil and make fertilizer recommendations. When CEC is measured and the pH exceeds 7.0, base saturation continues to increase. Measured CEC is the only way to determine base saturation on soils with pH 7.0 or higher. This is information you need to determine a program on how to handle the fate of ammonium and potassium in the soil. The sum of cations method will never work on calcareous (alkaline) soils. These labs that are trying to come into the calcareous west either do not know how to measure CEC or they are lazy false prophets of Albrecht.

Coleman and Mehlich did several experiments to demonstrate pH and base saturation. The only one I will refer to is the one with saturated montmorillonite clay with aluminum or hydrogen. (Figure4)

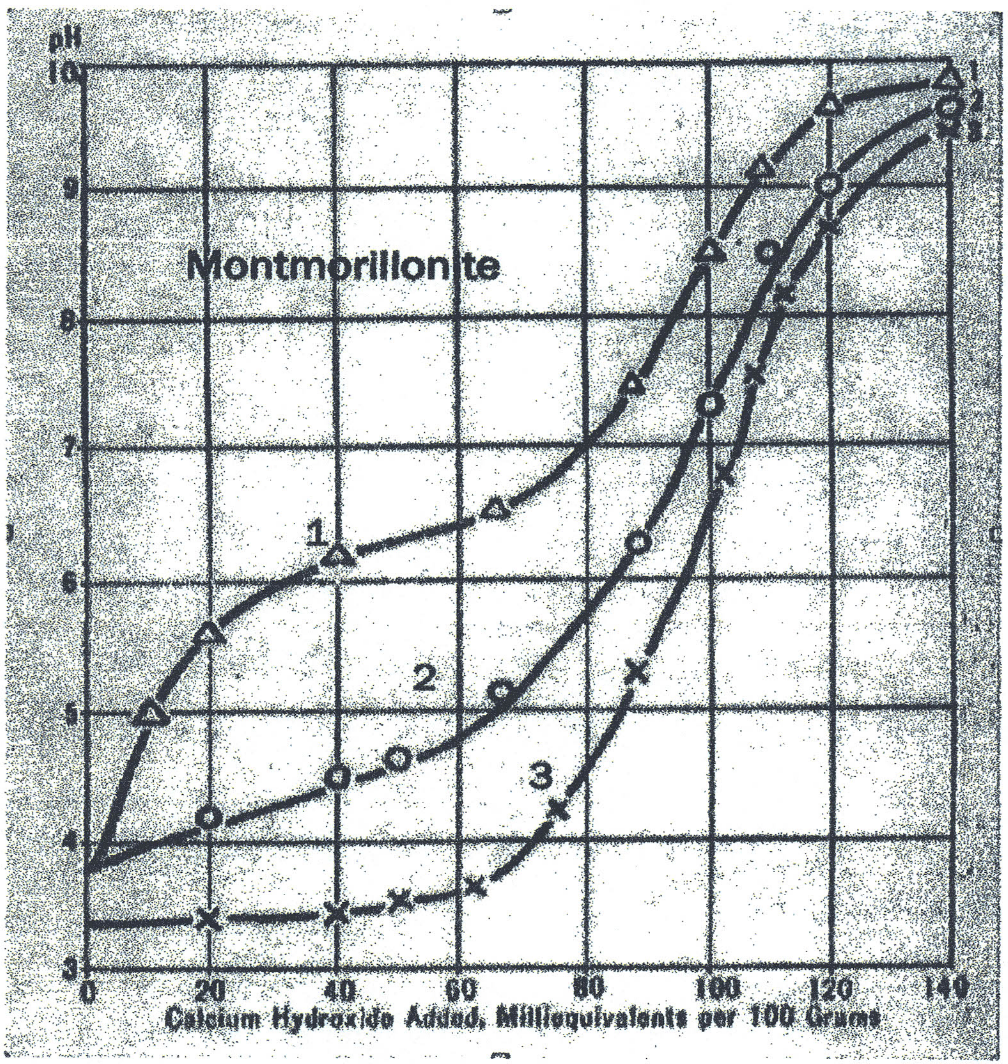

Figure 4

Line three was saturated with hydrogen which is more typical with rain in the western U.S.. Then, they added calcium and measured pH and % base saturation. Note that the pH of the clay was 3.3 (line 3) after all the cations have been replaced by hydrogen. Even when enough calcium was added to raise the base saturation above 60% the pH was still 3.7. As they continued to add calcium to the clay it dissected 100% base saturation at pH of 6.7. The base saturation continued increasing as they added calcium.

I have been criticized by many soil experts, which must have taken milk toast classes in college. It appears that is where our industry and society are headed. I was fortunate enough to attend Cal Poly in the early 1960"s and the five soil instructors were hard ass s.o.b.'s. They cared about our future and told us that we were cream and would rise to the surface in our careers. Out of the 22 soil science graduates in 1966 they all have done well. I am the late bloomer.

You have been taught that pH 6 contains 10 times more Hydrogen or is 10 times more acid than pH 7. Most of you were not taught that pH 8 contains 10 times more OH (hydroxyl ions) than pH 7. pH 8 is 10 times more alkaline than pH 7 or pH 8 contains 100 times less Hydrogen than pH 6. (Figure 5)

Relation of pH and pOH to Normalities of Acid and Alkaline Solutions

pH	Acid (normality of H)	Alkaline (normality of OH)	pOH
0	1.0	0.000,000,000,000,01	14
1	0.1	0.000,000,000,000,1	13
2	0.01	0.000,000,000,001	12
3	0.001	0.000,000,000,01	11
4	0.0001	0.000,000,000,1	10
5	0.00001	0.000,000,001	9
6	0.000001	0.000,000,01	8
7	0.000,000,1	0.000,000,1	7
8	0.000,000,01	0.000001	6
9	0.000,000,001	0.00001	5
10	0.000,000,000,1	0.0001	4
11	0.000,000,000,01	0.001	3
12	0.000,000,000,001	0.01	2
13	0.000,000,000,000,1	0.1	1
14	0.000,000,000,000,01	1.0	0

Figure 5

Fate of ammonium and potassium in acid soils

If you see a base saturation of 80, $NH4^+$ and K^+ are held on clay and humus. In figure 6 the soil solution is saturated with hydrogen. In figure 7 you see the ion replaceability in acid soils. Hydrogen is abundant in precipitation/irrigation, organic matter mineralization, manure application and fertilization. Hydrogen has a very small atomic radius but because of its abundance it can replace all of the other cations in areas with heavy rainfall. This is what makes soils acid. As the hydrogen concentration increases the pH decreases allowing aluminum and manganese solubility to increase. Applying lime or dolomite replaces hydrogen from the clay and humus and increases the calcium and magnesium concentration on the soil solution. Because of the high hydrogen concentration in acid soil the ammonium and potassium will replace the hydrogen on the clay and humus.

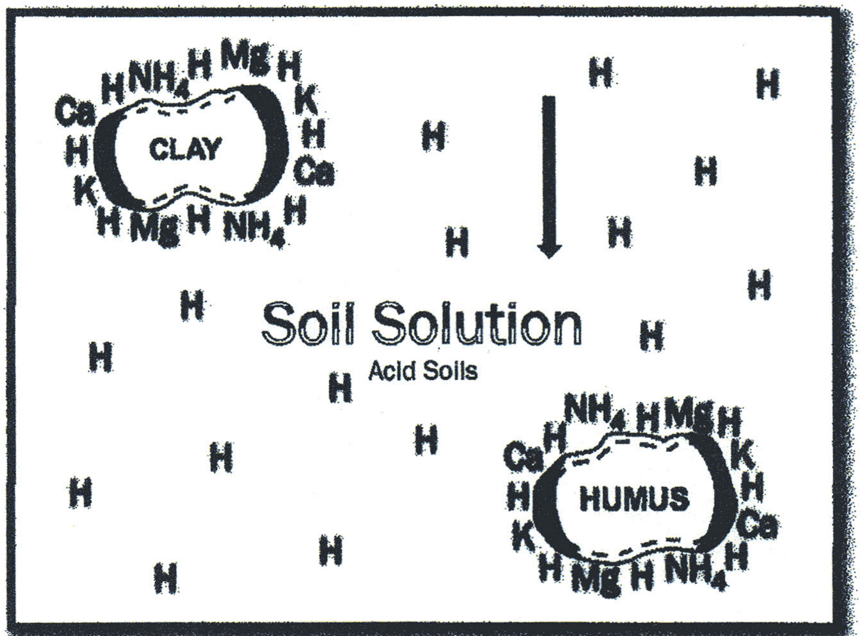

Figure 6

Ion Replaceability
in Acid Soils

$H^+ > Ca^{+2} = Mg^{+2} > K^+ = NH_4^+ > Na^+$

.53 .94 .65 1.33 1.01 .98

Atomic Radius

Angstroms

Figure 7

What is % TBS (Taberna Base Saturation)?
After 41 years of determining measured CEC and consulting potatoes and onions, I have determined that in calcareous soils $NH4^+$ and K^+ are in the soil solution and not held on clay or humus. % TBS (Taberna Base Saturation) is the percent chance of loosing your ammonium and potassium through heavy precipitation and over irrigation, which is calculated from measured CEC. The false prophets of Albrecht are running the % ABS, which is the Albrecht % Base Saturation using the sum of cations to determine CEC in calcareous soils.

Fate of ammonium and potassium in calcareous (alkaline) soil
If you see a base saturation of 169 %, there is a 69% probability (%TBS) that the $NH4^+$ and K^+ are in the soil solution and not held on clay and humus.

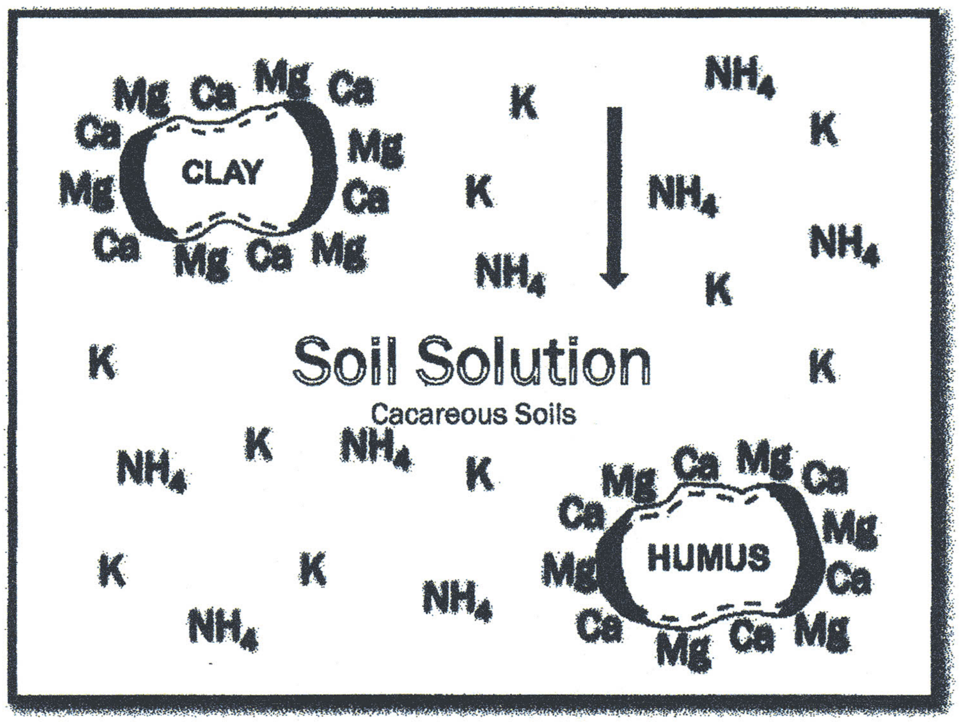

Figure 8

What does this mean?
Nutrients that are in the soil solution are prone to leaching through precipitation or irrigation. The higher the % TBS, the more management is required. If you apply all the potassium K^+ on pre-plant, and you get heavy rain or over-irrigation, the potassium K^+ will be leached below the effective root zone.

Why is this important?
Most farmers are not adding-up the cost of potassium K^+ being used by their crops. In 1973 they gave potassium-K^+ away. In 1985 potash was 7 cents per unit. Today it is over 80 cents per unit of actual K2O.

Figure 10 shows Calcium is the dominating cation. Calcium has an atomic radius of .94 angstroms (Figure 7). Most were taught that two potassium's would replace one calcium on clay and humus. This is true in acid soils but not in calcareous soils. All cations hydrate (swell) with water in the soil environment. When hydrogen hydrates it is the size of a grain of sand (Figuratively speaking). When calcium and magnesium hydrate they are the size of a pea (Figuratively speaking). When potassium and ammonium hydrate they are the size of grapes (Figuratively speaking). When sodium hydrates it is the size of a golf ball (Figuratively speaking). Note that calcium and magnesium are divalent ($^{++}$) cations and ammonium, potassium, and sodium are monovalent ($^{+}$) cations (Figure 9). This is why sodium deflocculates (disperses) in clays because it only has one charge and its hydrated size cannot satisfy two negatively charged clays. In calcareous soils calcium dominates. With excess calcium it precipitates and forms lime. It would take approximately 12,000 lbs. of elemental sulfur to dissolve 1% lime on a soil report. It would take an additional 3000 lbs. of elemental sulfur to lower the pH.

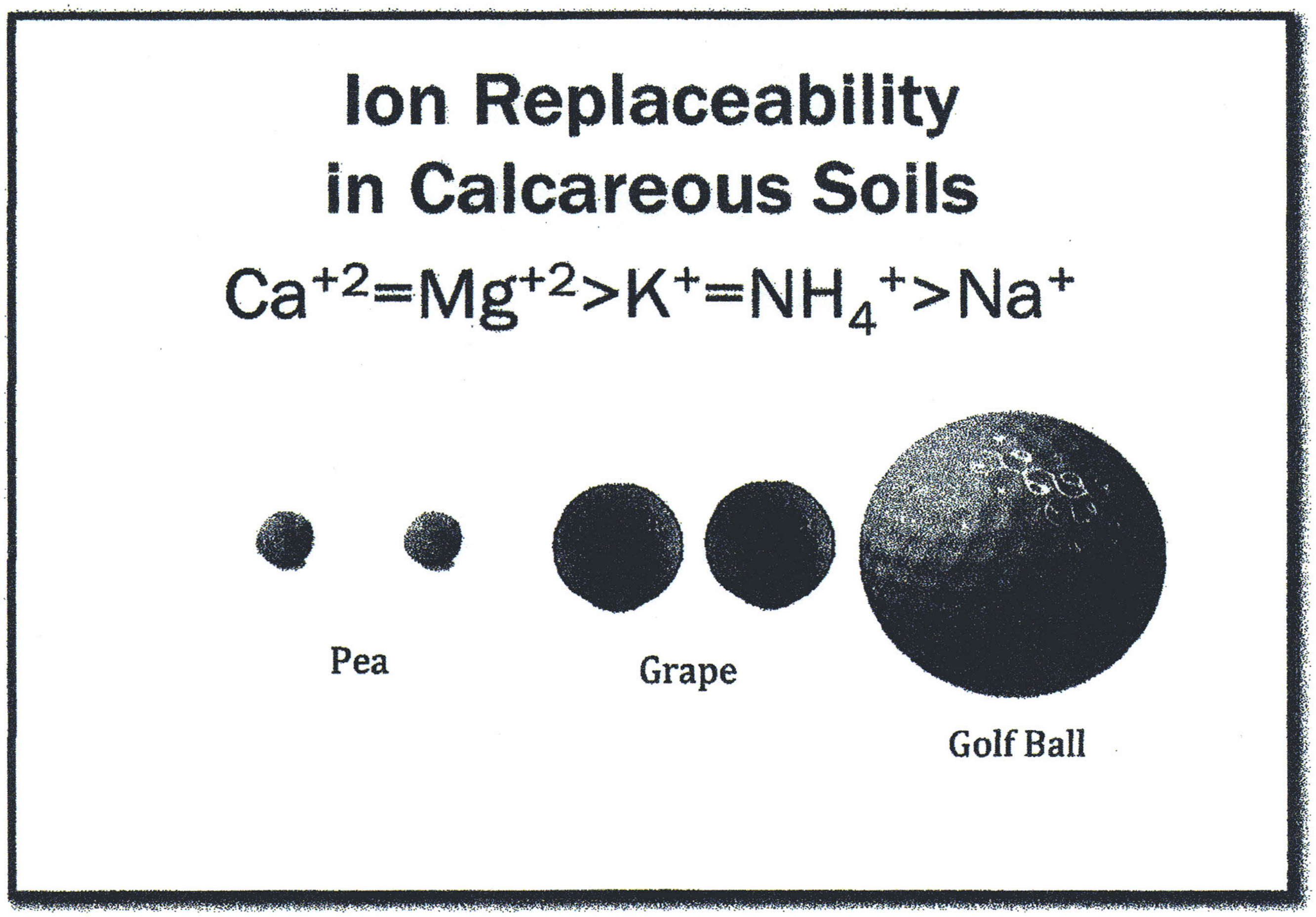

Figure 9

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Dealer:
Reported:
Test #:
Grower:
Field ID:

PAP-Accredited
NAPT
2011

Lab #:
33545

AGRICULTURAL SOIL REPORT

ELEMENT	ANSWER	INTERP	SHOULD BE	ELEMENT	ANSWER	INTERP	SHOULD BE
pH-Soil	7.9	Moderately Basic		Potassium-ppm	370	Adequate	300 +
pH-SMP				Potassium Bicarb	296	Medium	250 +
pH-CaCl				Sulfate-ppm	16	Low	20 +
Soluble Salts	0.35	Normal	< 1.5	Calcium-ppm	2465	Adequate	1,800 +
% Lime	L	1.5 to 3.0 % lime		Magnesium-ppm	405	Adequate	250 +
% Organic Matter	1.17	Very Low		Sodium-ppm	62	OK	< 225
Nitrates-ppm	27	Adequate	10 - 35	Zinc-ppm	2.0	Adequate	1.0 - 3.0
Ammonium-ppm	1	Low	5 +	Copper-ppm	1.6	Adequate	0.8 - 2.5
Phosphorus-ppm	34	Adequate	25 - 40	Manganese-ppm	4	Low	6 - 30
Phos-ppm-Bray			50 - 100	Iron-ppm	35	High	7 +
				Boron-ppm	0.5	Low	0.7 - 1.5

Texture	Sandy Loam
Cation Exchange Capacity - CEC	10
Percent Base Saturation	169

BASES	IDEAL	YOURS
Calcium-% of CEC	65-80	123
Magnesium-% of CEC	10-20	34
Potassium-% of CEC	2-6	9.5
Sodium-% of CEC	< 5	2.7
Hydrogen-% of CEC	< 15	

TBS%	P INDEX
69	73

	NO3 ppm	NH4 ppm
1 Ft	27	1
2 Ft		
3 Ft		
Total N PPM		28
Lbs N / Acre		84

Ratio	Ideal	Yours	Evaluation	Recommendations
Ca:Mg	6-20:1	6:1	OK	
Ca:P pH >7	100:1	73:1	OK	
Ca:P pH <7	40:1	:1		
P:Zn	15:1	17:1	High	Watch Zn

Fertilizer Suggestions in Pounds per Acre for the whole season		
Crop	Hops	Hops
Yield Goal	10 Bales	12 Bales
Past Crop		
Acres		
Nitrogen	66	96
Phosphate		12
Add Phos for P INDEX	55	
Potash		
Sulfates	18	28
Elemental Sulfur	87	
Gypsum		
Lime		
Dolomite		
Magnesium		
Zinc		2
Manganese		2
Copper		
Boron	1	2

Methods: www.westernlaboratories.com/methods.htm

Remarks:

Add 40# Phosphate as starter if soil temps < 50F at planting

Split apply Nitrogen. Tissue and soil test in-season gives the best results

"Always practice the laws of Agronomy."
John P. Taberna, Soil Scientist

Figure 10

In the mid 80's Dr. Robert Stevens coauthored Tree Fruit Nutrition at Washington State University. Bob was the state soil scientist, now retired, who was a great asset to Washington agriculture. Figure 11 is the face of this book and Figure 12 is found on page 36 of his book.

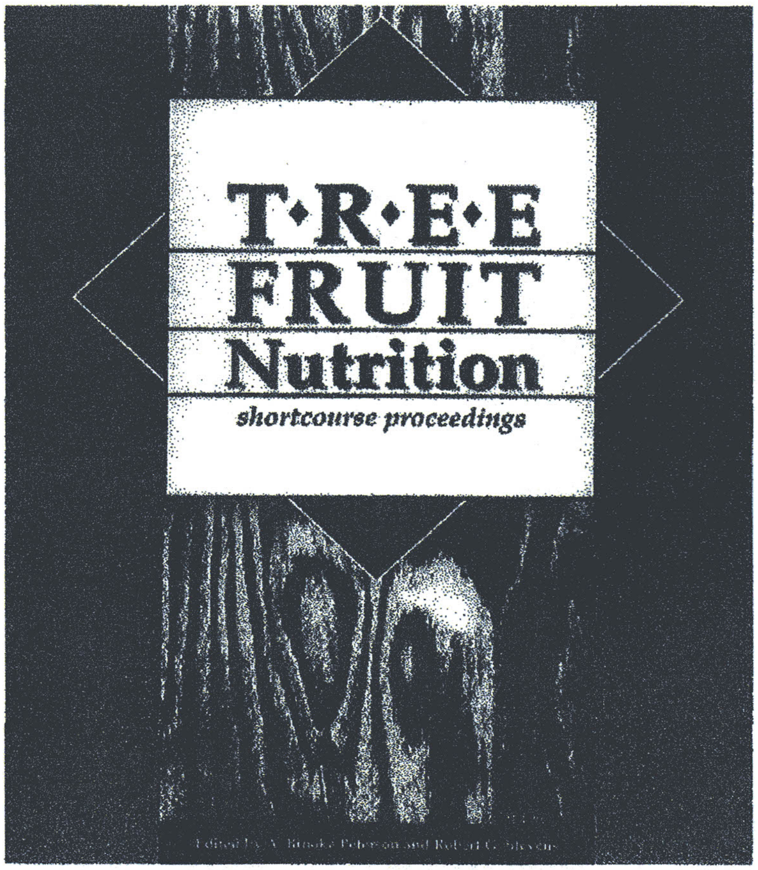


Figure 11

Chemical characteristics of several Wenatchee, Washington orchard soils.						
pH	EXCHANGEABLE BASES Meq/100g				CEC	BASE SATURATION
	Ca	Mg	K	Na		%
4.3	6.20	1.59	0.62	0.12	18.83	45
4.2	1.7	0.30	0.17	0.08	6.16	36
7.2	3.90	0.55	0.34	0.10	4.76	103
9.2	19.65	0.86	7.10	1.01	10.05	285

Figure 12

Figure 12 is where Dr. Stevens measured the millequivalent calcium, magnesium, potassium, and sodium. He then measured Cation Exchange Capacity (CEC), which is also in Meq/100g. In figure 13, I compare measured CEC to sum of the cations calculated CEC.

Chemical characteristics of several Wenatchee, Washington orchard soils								
pH	EXCHANGEABLE BASES Meq/100g				CEC	CEC	% BASE SATURATION	
	Ca	Mg	K	Na	Meas.	Calc.	Meas.	Calc
4.3	6.20	1.59	0.62	0.12	18.83	8.53	45	100
4.2	1.7	0.30	0.17	0.08	6.16	2.25	36	100
7.2	3.90	0.55	0.34	0.10	4.76	4.89	103	100
9.2	19.65	0.86	7.10	1.01	10.05	28.62	285	100

Figure 13

If you take the pH 4.3 and add calcium + magnesium + potassium + sodium you get 8.53 calculated CEC. I did not do the calculations for Hydrogen because no matter what the pH is using, the Bear/Albrecht % base saturation always adds up to 100%.

Looking at pH 7.2, note the calculated and measure CEC are similar. Remember, Coleman and Mehlich stated that neutral soils are base saturated. You can see that this applies to Dr. Stevens work in Washington.

Looking at pH 9.2, shows a large discrepancy between measured CEC and calculated sum of the cations. You will never find the problem soil using sum of the cations on pH greater than 7.2.

Is Rutgers the only university that gets it?
I receive many samples from the east coast where large amounts of lime are purposefully being used to raise the pH above 7.4. My client sent some samples to Rutgers and you will notice they use the Mehlich extracting procedure (Figure 14). Note the pH of the soil is 7.52 and they make a statement declaring:

Estimated Cation Exchange Capacity and Basic Cation Saturation
CEC cannot be calculated for samples with pH greater than 7

RUTGERS
New Jersey Agricultural
Experiment Station

Soil Testing Laboratory
Rutgers, The State University
ASB II
57 US Highway 1 South
New Brunswick, NJ 08901-8554

Soil Test Report
Lab #: 2011-10566

Name:

Address:

Phone:
Fax:
Email:

Date Received: 2011-05-23
Date Reported: 2011-06-09

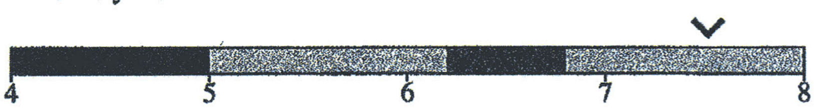
Sample ID: Zone 2

Crop or Plant
Est. Ornamental shrubs and small trees, non-acid-loving

Soil Tests and Interpretations

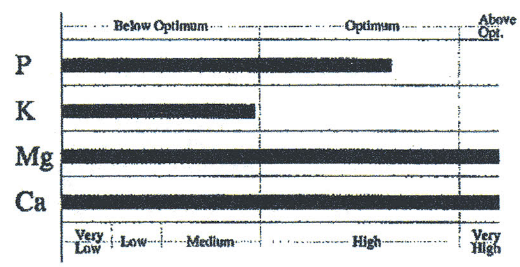
Loam

pH: 7.52 Moderately alkaline



Macronutrients (pounds per acre)

Phosphorous:	115	(Optimum)
Potassium:	142	(Below Optimum)
Magnesium:	572	(Above Optimum)
Calcium:	2357	(Above Optimum)



by Mehlich 3 extraction

Micronutrients (parts per million)

Zinc(Zn)	Copper(Cu)	Manganese(Mn)	Boron(B)	Iron(Fe)
46.09 (Adequate)	0.91 (Adequate)	9.87 (Adequate)	0.87 (Adequate)	168.80 (High)

Estimated Cation Exchange Capacity and Basic Cation Saturation

CEC cannot be calculated for samples with pH greater than 7

Special Tests Results

Soil Textural Class: Loam

Figure 14

In Summary

If your lab is not running measured CEC on soil a pH greater than 7 you are not getting a true picture of the behavior of ammonium and potassium in saline soils. If you apply 300 lbs. potassium pre-plant at 90 cents per unit and the farmer proceeds to over irrigate or there is heavy early season precipitation that occurs, how are you going to explain what happened. You are supposed to be the expert and they trust you. Figure 15 is showing that you have sandy soil and there is a 69% chance that heavy precipitation or over irrigation will move the potassium and ammonium below the effective root zone. You need to come up with a different program for potassium and ammonium.

Texture	Sandy Loam	
Cation Exchange Capacity - CEC		10
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Figure 15

John P. Taberna
Soil Scientist
2012

Go to westernlaboratories.com and click on bulletins-events-tutorial for other information that could be useful.