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EVALUATION OF SENSORS FOR IMPROVED NITROGEN RECOMMENDATIONS IN SPRING WHEAT PRODUCTION

By Olga S. Walsh — Western Triangle Agricultural Research Center, Montana State University

The increasing interest in precision agriculture tools such as remote sensors is apparent among crop producers. Using remote sensors allows accounting for temporal and spatial variability and results in more efficient and profitable crop production. Crop canopy reflectance measurements are often reported as indexes such as Normalized Difference Vegetative Index (NDVI) (Tucker, 1979). Crop reflectance is used to develop algorithms for mid-season topdress N fertilization (Raun et al., 2001).

In 2011, a spring wheat study was conducted at Western Triangle Agricultural Research Center (WTARC) near Conrad, MT, and Western Agricultural Research Center (WARC) near Corvallis, MT. The study evaluated two sensors – GreenSeeker (GS) and Pocket Sensor (PS) – for determining fertilizer N rates. The GS provides accurate crop reflectance measurements that can be used to index N response, crop condition, yield potential, stress, pest and disease impact (http://www.trimble.com/, 2010). The PS was initially designed for the developing regions of the world where farmers have limited funds to invest in technologies. The PS is about the size of a cellular phone and costs only about 10% of the GS system.

Additionally, this study assessed whether N recommendations should be adjusted depending on the fertilizer N source. Two most common N sources in Montana – granular urea and liquid urea ammonium nitrate (UAN) were evalu-

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DETECTING AND CORRECTING SOIL CALCIUM LIMITATIONS

By Tim K. Hartz, Mike Cahn and Richard Smith — University of California

The issue of calcium (Ca) availability in alkaline, mineral soils has long been a matter of contention. Based on the commonly used 'exchangeable cations' test (ammonium acetate extraction), most Western soils are well supplied with Ca. However, in alkaline soils, a substantial percentage of 'exchangeable' calcium identified by this test can be in chemical forms not readily available to plants or active in soil solution. In California, calcium-related physiological disorders such as tipburn on lettuce and blossom end rot of tomatoes and peppers are distressingly common. Vegetable growers here use significant quantities of calcium-based fertilizers and amendments to combat these disorders, and to improve postharvest quality. We conducted an extensive two-year study on soil calcium relations, attempting to answer three fundamental questions.

1. How plant-available is calcium in California soils?

To evaluate soil Ca availability we collected a set of 20 representative agricultural soils from fields in vegetable rotations in the Sacramento, Salinas, San Joaquin and Santa Maria Valleys. These soils were chosen to represent a range of texture (sandy loam to clay), pH (6.7 - 7.8) and calcium status. Air-dried samples (top foot of soil) were analyzed for cation content (Ca, Mg, K and Na) by two standard laboratory tests:

- 'exchangeable' cations by ammonium acetate extraction

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Head Editor—Amber Moore, University of Idaho; Guest Editor-Stuart Pettygrove, University of California

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- 'soluble cations' by saturated paste extraction

Additionally, to simulate the actual cation content of soil water, each soil was wetted to field capacity, allowed to equilibrate overnight, and then spun in a laboratory centrifuge at high speed to extract liquid solution from the soil. These solutions were analyzed for cation content.

Soil solution Ca in these soils was quite high, ranging from 5 - 80 milliequivalents/liter and averaging 34 meq/liter. Since each meq/liter equals 20 PPM, soil solution Ca ranged from 100 - 1,600 PPM Ca, averaging about 680 PPM. As a standard of comparison, consider hydroponic nutrient solutions used in greenhouse vegetable production. These solutions, formulated to provide optimum levels of all nutrients, typically contain only 150-250 PPM Ca; all but one of the soils tested had soil solution Ca greater than 200 PPM.

Using soil solution obtained by centrifugation as the standard of accuracy for predicting soil calcium availability, saturated paste Ca was a much more accurate estimation of soil Ca status than was ammonium acetate extraction. There was no correlation between soil solution Ca and ammonium acetate exchangeable Ca (Fig. 1), but there was a good correlation between saturated paste Ca and soil solution Ca (r = 0.88). However, on average the saturated paste extract had only 19% of the Ca concentration in soil solution; multiplying the saturated paste Ca concentration by 5 gave a good estimate of the Ca concentration in soil solution.

2. What role does soil calcium availability play in calcium disorders?

We chose to focus on tipburn in romaine lettuce, one of the more common calcium-related disorders of vegetable crops. Fifteen Salinas Valley romaine fields were sampled in 2005-06. Soil samples (top foot) were collected and analyzed for Ca by saturated paste extraction. At commercial maturity 24 plants per field were evaluated for tipburn severity, defined as the number of inner leaves showing tipburn.

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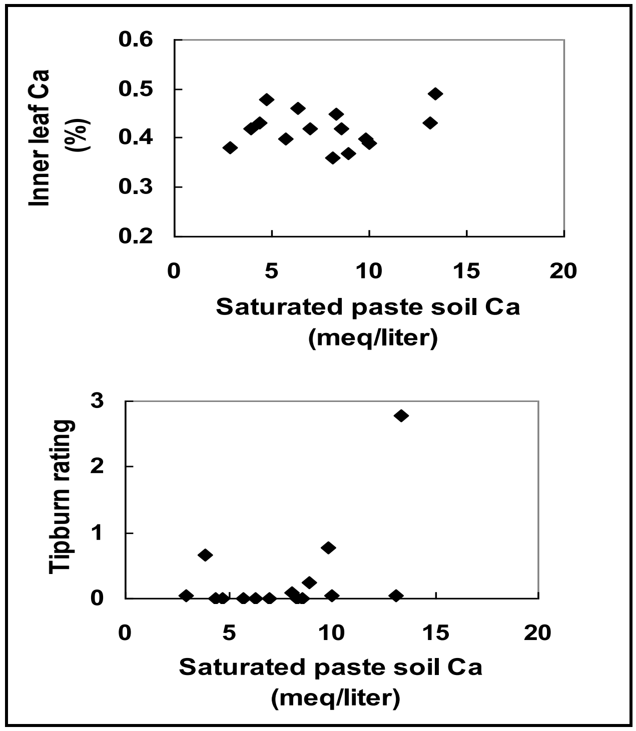

Figure 2. Relationship between soil calcium supply and inner leaf Ca concentration and tipburn severity; tipburn rating was the mean number of affected leaves per plant.

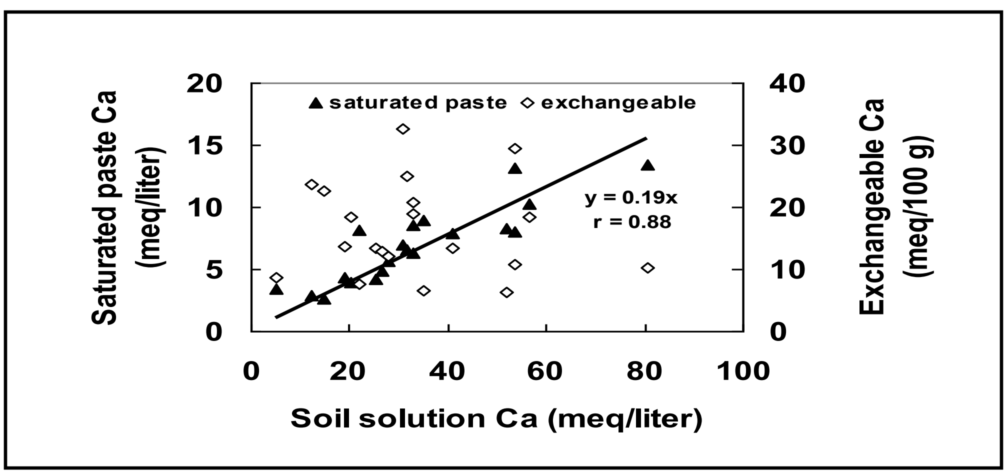

Figure 1. Relationship between soil exchangeable Ca or saturated paste Ca and Ca concentration of soil solution extracted by centrifugation.

Detecting and Correcting Soil Calcium Limitations, continued from pg. 2

Inner leaves were oven-dried and analyzed for Ca.

Three of the 15 fields had significant tipburn. There was no relationship between soil Ca availability and either inner leaf Ca concentration, or tipburn severity (Fig. 2). There was, however, an apparent link between environmental conditions and tipburn. Two of the three fields with significant tipburn were located near the coast, and encountered persistent foggy weather from 6-10 days before harvest. The reduced transpiration during that period may have temporarily limited the supply of Ca moving into the developing leaves, resulting in a transient Ca deficiency. Other research on lettuce tipburn has also identified limited transpiration as the underlying cause of the disorder.

3. Is calcium fertigation effective in improving crop calcium uptake and product quality?

We evaluated calcium fertigation on romaine lettuce, cantaloupe and honeydew to test claims that supplemental calcium can suppress lettuce tipburn, and increase fruit firmness in melons. Two drip-irrigated trials were conducted on melons, a 2005 trial on honeydew and a 2006 trial on cantaloupe. In the 2005 trial three Ca fertilizers [calcium nitrate (CN), calcium thiosulfate (CATS) and calcium chloride (CC)] were fertigated during fruit development in three weekly applications of 10 lb Ca/acre, for a seasonal total of 30 lb Ca/acre. In 2006 two applications of 15 lb Ca/acre from CATS or CC were made. These fertigation rates were similar to those in commercial use. Treatments were replicated 5 times in 2005, and 4 times in 2006. At commercial harvest stage fruit yield, soluble solids concentration (SSC, ^{o}brix) and flesh firmness were compared among the Ca fertilizers and a control treatment receiving no fertigated Ca. Additional fruit were evaluated for SSC and firmness after refrigerated storage of 14 days (2005) or 7 days (2006). Fruit flesh samples were analyzed for Ca concentration.

Two trials were conducted on romaine lettuce in 2005 to evaluate the effects of fertigated Ca on romaine yield and expression of tipburn; a third trial was conducted in 2006. In 2005, CN, CATS and CC fertigation were compared with a control treatment not receiving fertigated Ca. Two applications of 15 lb Ca/acre each were made approximately 14 and 7 days before harvest. In the 2006 trial a single application of either CN or CATS was made at 25 lb Ca/acre a week before harvest. In all trials treatments were replicated 5 times. At commercial maturity plant weight, tipburn severity and Ca concentration of inner leaves (those most susceptible for tipburn) were measured.

In neither melon experiment did fertigated Ca significantly increase fruit yield, SSC or flesh firmness. Melon flesh Ca concentration was unaffected by Ca fertigation. Similarly, applying calcium fertilizers through surface drip irrigation had no measurable effects on romaine yield or Ca concentration in the inner leaves of the head. No tipburn was observed in any treatment in the first trial; a low level of tipburn was detected in the second trial, but Ca fertigation did not reduce it.

The lack of benefit from Ca fertigation can be explained by considering the relatively high level of available Ca at these sites (which were representative of the production areas), and the limited amount of Ca applied (also representative of current commercial practices). Thse fields averaged 5.4 meq Ca/liter, or about 110 PPM Ca; based on the soil calcium availability study, Ca in soil solution would be about 5 times higher, or 550 PPM. This means that, at field capacity moisture content, Ca in the soil solution in these fields averaged approximately 200 lb/acre in the top foot of soil. The application of 10-15 lb Ca/acre in an irrigation would thus represent only a small increase in soluble Ca.

The other factor limiting the effectiveness of Ca fertigation is the close connection of Ca uptake with plant transpiration. Since Ca moves mostly in transpirational flow, Ca concentrates in the most actively transpiring tissue – fully exposed leaves. Due to the waxy rind, melon fruit (and fruits in general) have very limited transpiration. Similarly, the inner leaves of romaine, protected within the head, transpire much less than older, more exposed leaves. Even if one is successful in substantially increasing plant Ca uptake, little of that additional Ca is likely to move into these Ca-sensitive plant parts.

Conclusions

Western mineral soils generally have high calcium availability; the only common exception to this rule would be very sandy soils, which have low levels of all cations due to limited cation exchange capacity. The most appropriate laboratory test to determine soil Ca status is saturated paste extraction. At the modest rates at which they are typically applied, calcium-containing fertilizers will have little effect on crop Ca status, or the occurrence of calcium-related disorders such as tipburn or blossom-end rot. These disorders do not usually occur due to low soil Ca availability, but rather are induced by factors such as soil water stress or low ET_o, resulting in a transient deficiency ■

Evaluation of Sensors for Improved Nitrogen Recommendations in Spring Wheat Production, continued from pg. 1

ated. The treatments are detailed in Table 1. Sensor readings were collected at the early jointing growth stage to estimate N uptake and biomass. Only grain yields are reported in this article. Topdress N fertilizer was applied as urea (as dry prills, manually broadcasted) or as UAN (as a foliar spray, using a battery operated backpack sprayer) immediately following sensor readings. Topdress N rates were determined using two spring wheat algorithms - Spring Wheat, Canada (SWC) and Spring Wheat, US/Canada/Mexico (USCM) -- and a Generalized Algorithm (GA) recently proposed for N recommendations in any cereal crop independent of the growing region. The information about these and other algorithms is available at: http://www.soiltesting.okstate.edu/SBNRC/SBNRC.php.

The SWC and the GA algorithms suggested that no topdress N was needed to reach the crop yield potential at both locations. The USCM algorithm recommended application of 0 to 35 lbs N/ac at WTARC and from 0 to 71 at lbs N/ac WARC depending on the wheat reflectance values. Topdressing N rates shown in Table 1 represent the average for each preplant rate treatment as prescribed by the USMC algorithm.

Mean grain yields ranged from 829 to 2378 lbs/ac at WTARC and from 1822 to 3558 lbs/ac at WARC (Table 1). At the WTARC location, N topdressing applied at rates based on the USMC algorithm was apparently insufficient to increase yields to the level attained with the very high preplant rate of 220 lb N/acre.

At the WARC location, grain yields were considerably higher than those measured on the WTARC plots. Plots receiving preplant rates of 60 and 80 lb N/acre plus topdressing yielded equal to or nearly as well as the plots receiving the 220 lb N/acre preplant rate; but as this treatment also received a similar topdressing N, it is not possible to separate the yield response to preplant N rate and topdressing N rate.

There were no significant differences in yields associated with N source, suggesting that N rates should not be adjusted based on N source used. Also, there was no apparent trend in grain protein associated with N rates or sources (data not shown).

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Table 1. Treatment structure and spring wheat grain yield, WTARC and WARC, 2011.

Treatment	*Preplant N Rate, lb N ac^{-1}	**Topdress N Source	Topdress N Rate, lb N ac^{-1}		***NDVI		****Mean Grain Yield, lbs N ac^{-1}	
			WTARC	WARC	WTARC	WARC	WTARC	WARC
1	0	-	-	-	0.24	0.40	829 (f)	1822 (f)
2	220	urea	18	19	0.35	0.52	2378 (a)	3335 (abc)
3	20	urea	18	26	0.33	0.46	1369 (e)	2488 (d)
4	40	urea	18	6	0.35	0.56	1388 (e)	3061 (bc)
5	60	urea	18	13	0.37	0.55	1662 (cd)	3453 (abc)
6	80	urea	9	19	0.38	0.56	1925 (b)	3558 (a)
7	20	UAN	26	26	0.33	0.51	1298 (e)	2907 (cd)
8	40	UAN	18	6	0.35	0.58	1465 (de)	3136 (abc)
9	60	UAN	9	6	0.40	0.57	1771 (bc)	3004 (bc)
10	80	UAN	9	13	0.41	0.55	1935 (b)	3210 (abc)

* Preplant N was applid as urea. ** Todress N rates were determined using wheat reflectance measurements and Spring Wheat (US/Canada/Mexico) algorithm. ***NDVI values averaged for each treatment over four replications. **** Means in the same column, followed by the same letters are not significantly different (t-test, $p<0.05$).

Evaluation of Sensors for Improved Nitrogen Recommendations in Spring Wheat Production, continued from pg. 4

Both sensors performed well in the field, and reflectance measurements were moderately well correlated with grain yield (Figures 1 and 2). This supports reports from other researchers that sensor-based technologies have the potential to estimate grain yield.

Montana's predominantly no-till practice where pale colored residue and stubble are present in the field at the time of sensing may have resulted in lower NDVI values. Montana's colder temperatures early in the growing season cause the wheat canopy to close slower and later, also resulting in lower NDVIs. Thus, yield potential may be underestimated and lower N rates may be prescribed. The results emphasizes the importance of several recently initiated projects focused on evaluation of sensors and underlines the need for timely development of crop-specific and region-specific algorithms for the benefit of producers.

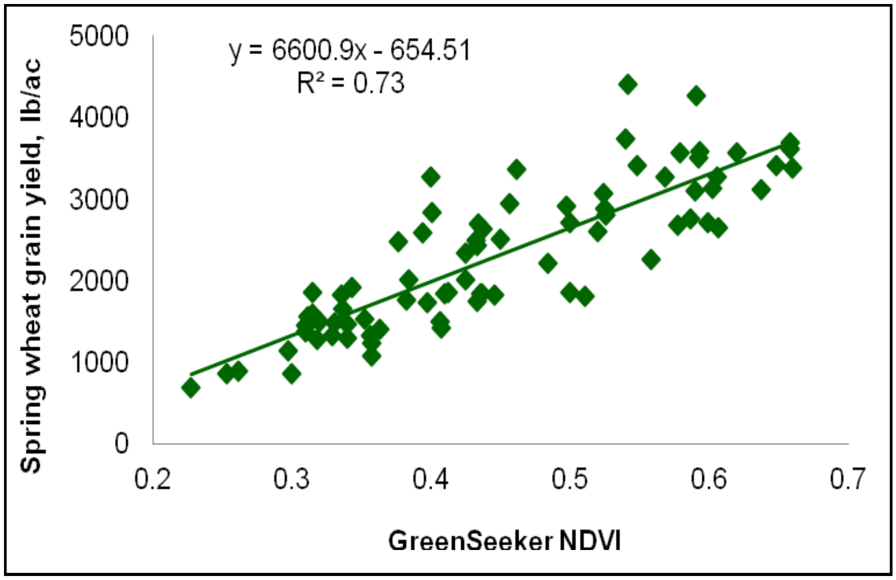

Figure 1. Relationship between GreenSeeker NDVI and spring wheat grain yield, WTARC and WARC (combined locations), 2011.

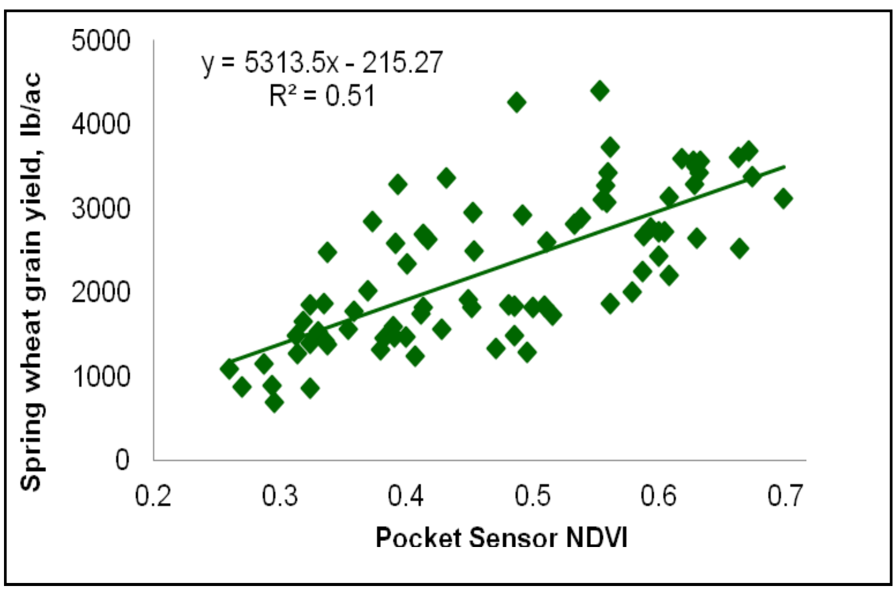

Figure 2. Relationship between Pocket Sensor NDVI and spring wheat grain yield, WTARC and WARC (combined locations), 2011.

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WHERE DO FERTILIZERS COME FROM?

By Rob Mikkelsen — Western North America International Plant Nutrition Institute

There is both a simple answer and a complex answer to the question of where fertilizers come from. The simple answer is fertilizers are mined from the earth or processed from naturally occurring resources. The more complicated answer is that fertilizer materials are internationally traded commodities and the fertilizer you are using may have started its journey from almost anywhere in the world.

NITROGEN FERTILIZER

Dinitrogen gas (N_2) is extremely stable in the atmosphere and it is difficult to change it into a form that plants can use for nutrition. All N fertilizer begins by combining hydrogen gas (H_2) with N_2 from the atmosphere. Since the H_2 required for ammonia synthesis largely comes from natural gas, the price of this gas is a major factor in the cost of ammonia. Higher energy costs translate directly into higher prices for all N fertilizers. All commercial N fertilizer begins as ammonia and then is converted to other N products. Over 90% of all ammonia is used for fertilizer in its various forms.

In the U.S., two underground pressurized pipelines with a total length of over 3,000 miles transport liquid ammonia throughout the Midwest. In Western North America, ammonia arrives at the Pacific coast in ships from foreign countries or in railroad cars from the Midwest or the Gulf States.

Over half of the ammonia produced is converted to urea fertilizer through the reaction of ammonia and carbon dioxide. Urea is by far the most widely used N fertilizer worldwide.

A growing quantity of urea is used to control air pollution from power plants and vehicles. Most new diesel trucks use Selective Catalytic Reduction controls to reduce harmful gases. This is done by spraying exhaust gas with a fine mist of urea, which breaks down to ammonia and eliminates NO_x emissions.

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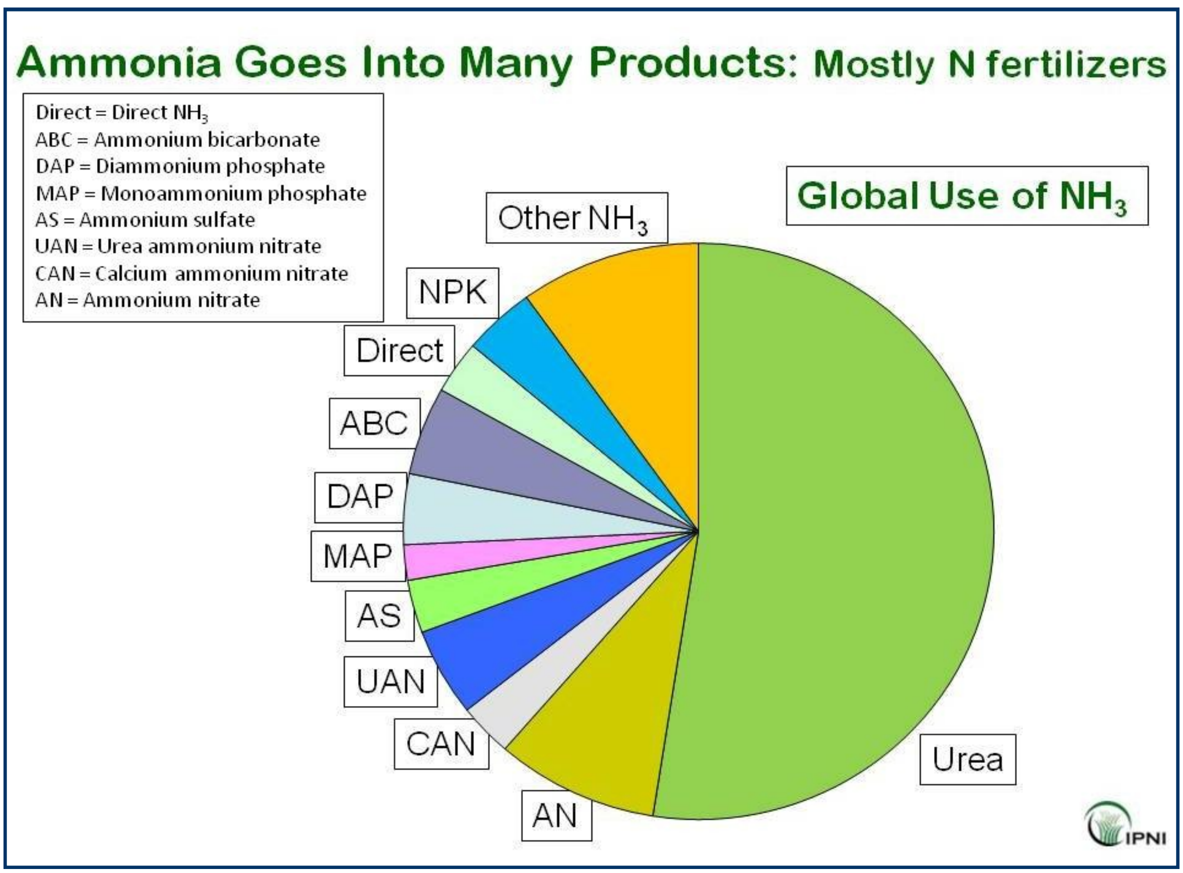
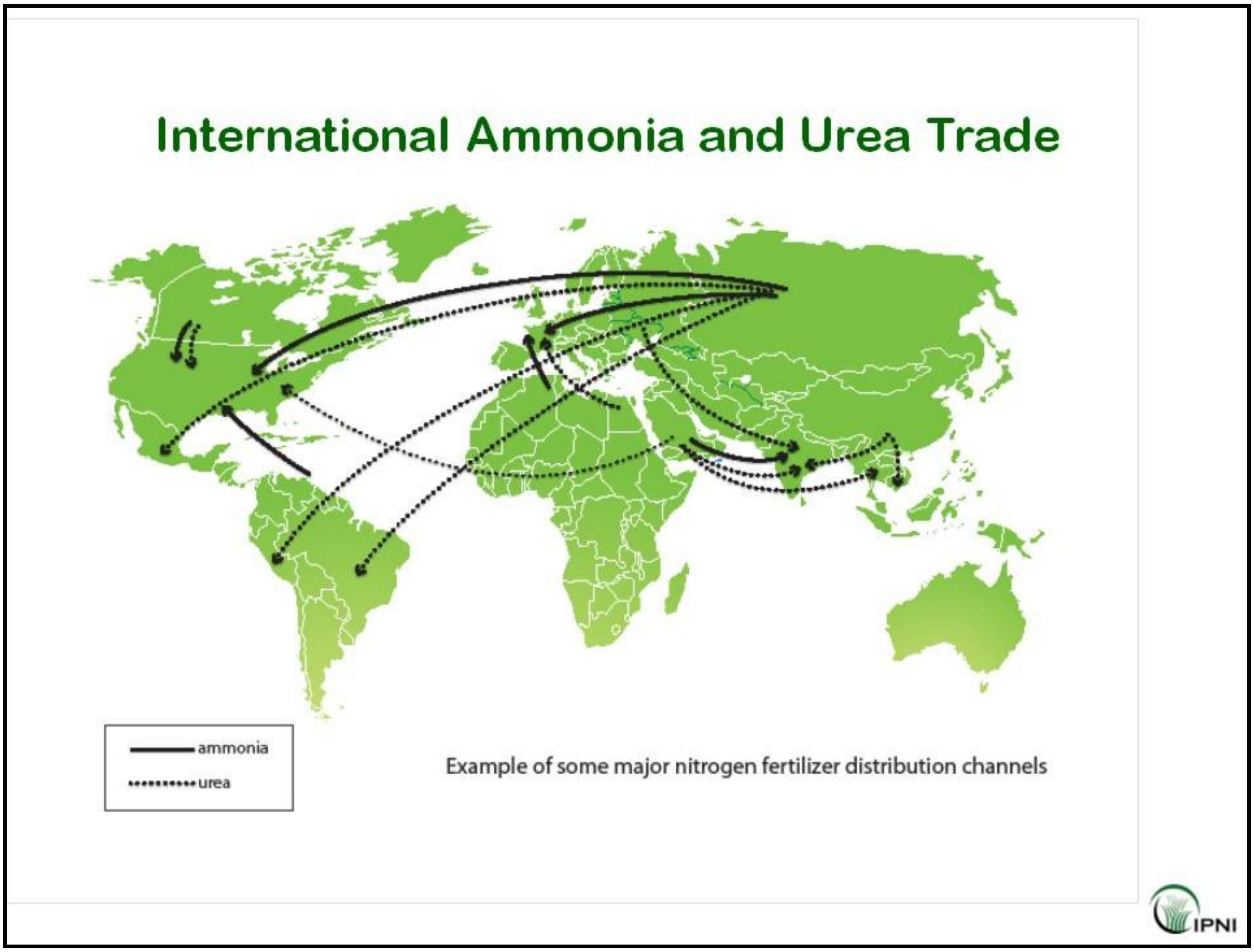


Where do Fertilizers Come From?, continued from pg. 6

Both ammonia and urea are widely traded on the international markets. More information can be found at: http://www.ittybittyurl.com/cnk.



PHOSPHORUS FERTILIZER

Phosphorus fertilizer reactions in soils can be quite complex. Crops take up dissolved inorganic P from soil water, and because soil solution P concentration is usually very low it must be continually replenished over the life of the plant to meet P demands.

The raw rock phosphate is mined from the earth to extract a mineral called apatite. Phosphate rock is mined in many countries. The "Western Phosphate Field" of the U.S. (Idaho, Utah, Wyoming, and Montana) contains one of the largest resources of P rock in the world and has been mined for more than a century. Over 250 million metric tons of phosphate rock has been extracted from 70 commercial mines during that period. Phosphate rock mining presently only occurs in Idaho, Wyoming, and Utah.

After mining the rock phosphate, common impurities such as clay and sand are removed in a process called beneficiation. The ore is then reacted with sulfuric acid to dissolve the P from the rock and produce the raw material for making almost all commercial P fertilizers.

Although recent estimates of global P supplies indicate that there are several hundred years of reserve still available for mining, efforts should be made to use these natural resources as wisely as possible. Additional information can be found at: http://www.ittybittyurl.com/cnn.

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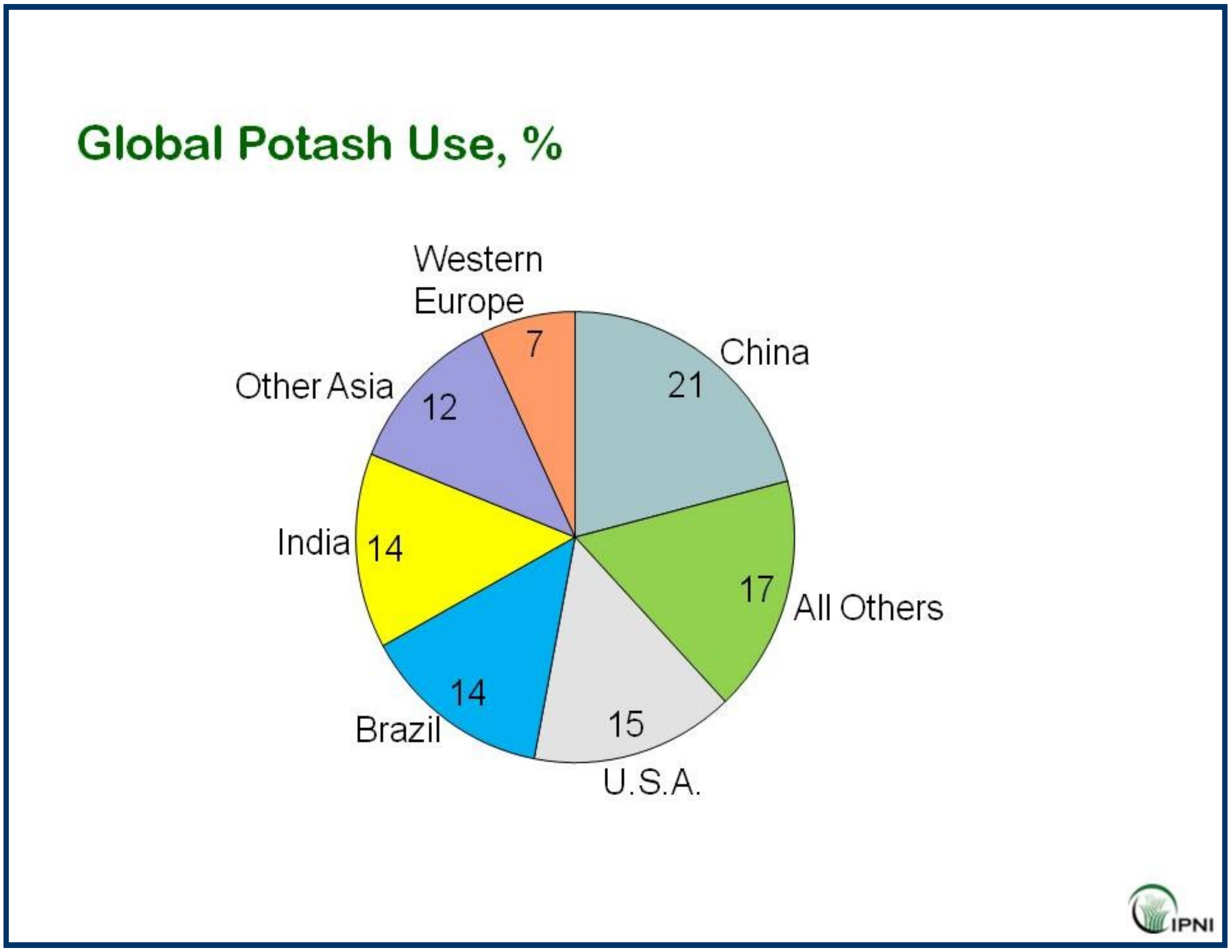
POTASSIUM FERTILIZER

Potassium is one of the essential plant nutrients found in high concentrations in plants. It is also an essential mineral nutrient for both animal and human nutrition.

Underground salt deposits are the primary source of potash fertilizer. These deposits were formed as ancient oceans evaporated, leaving behind concentrated salt layers that were subsequently buried by sediment. The largest potash deposits are found in central Canada, but valuable sources of U.S. potash are obtained from New Mexico and Utah. Potash is obtained by one of three methods: (i) conventional shaft mining [such as near Carlsbad, NM] (ii) solution mining [such as near Moab, UT], or (iii) evaporation of surface brine such [such as from the Great Salt Lake or the Bonneville Salt Flats in Utah].

A mixture of potassium chloride and sodium chloride is the dominant material obtained from actively mined deposits. In the geologically unique New Mexico deposit, langbeinite ($K_2SO_4 \cdot 2MgSO_4$) is also present. Potassium sulfate (K_2SO_4) is obtained from the Great Salt Lake in Utah. Additional information can be found at: http://www.ittybittyurl.com/cnp.

Regardless of where your fertilizer comes from, these valuable nutrients are in demand within global agricultural markets. Even farmers living close to the mine or the fertilizer factory are competing with farmers around the world for these plant nutrients. This can make prices seem unpredictable sometimes and subject to economic factors that may be ■ difficult to understand. The best solution is to precisely know the type and quantity of nutrients required to achieve your yield goals and then manage those nutrients in the best possible way to maximize their efficiency.



QUESTIONS FROM THE FIELD IN THE LAND OF ENCHANTMENT: WHAT CAN I DO TO MAKE THE BEST OF A BAD WATER YEAR?

By Robert Flynn — New Mexico State University

A continuing drought and very limited water allocations from several irrigation districts are prompting farmers and ranchers to turn to groundwater resources with questionable quality. Ranchers are exploring methods of reducing sulfate levels that exceed 2000 ppm. Irrigation districts will soon release water for irrigated crops but at levels far below the consumptive use required of the major crops of alfalfa, corn and pecans. Soil testing can still provide valuable information for determining a plan of action to limit the effects of limited water and commensurate salinity control.

The top 5 things to do:

1) Determine the salinity of the fields to be used with limited water.

It is better to determine the soil salinity using the saturated paste extract, symbolized by ECe. A saline soil is, by definition, a soil with an ECe greater than 4 mmhos/cm or dS/m and a pH < 8.2 and no sodium concerns. The graph below shows salinity measurements from the same soil done by 1:1 water:soil extract versus saturated paste (ECe). Many labs will run a 1:1 water:soil extract. However, the 1:1 extract can miss the definition of a saline soil and would cause an incorrect interpretation for plant response (Figure 1).

Plants differ in their response to salinity, making it essential to know the correct salinity level so that leaching fractions can be determined to maintain yield or avoid excessive yield loss.

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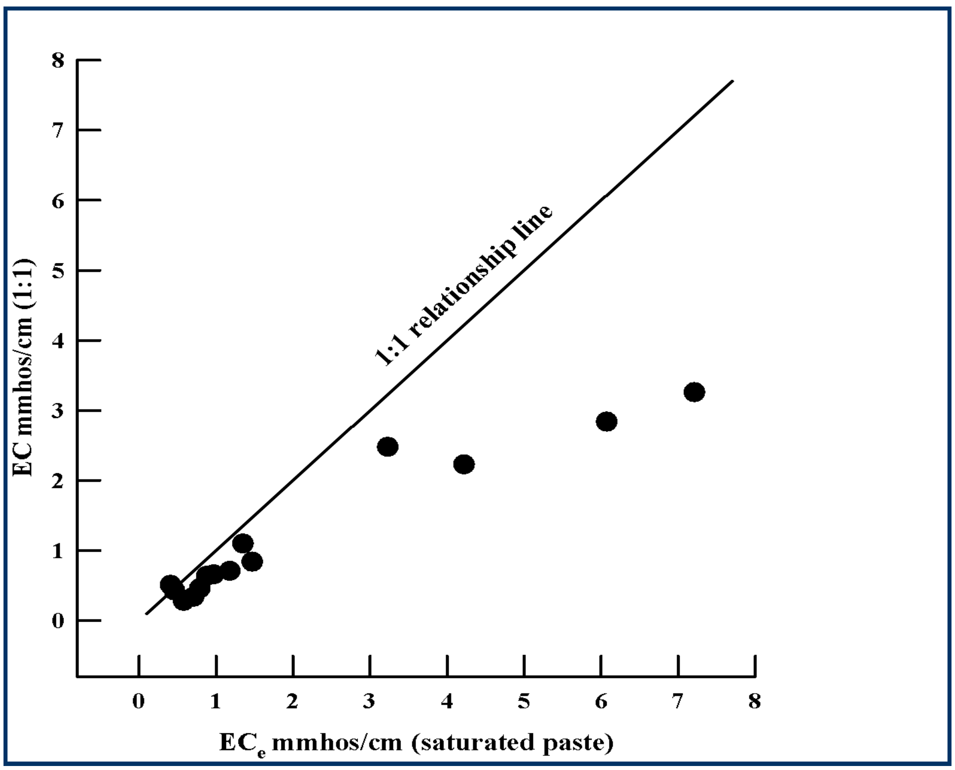

Figure 1. Soil electrical conductivity (EC) as determined by 1:1 vs saturated paste extract (ECe).

2) Determine what crops might work under saline vs non-saline conditions.

The following are examples:

Tolerant Crops		Sensitive Crops	
Crop	Threshold EC_e (mmhos/cm or dS/m)	Crop	Threshold EC_e (mmhos/cm or dS/m)
Alfalfa, selected varieties †	>4.0	Alfalfa, general	2.0
Bermudagrass hay	6.9	Sudangrass	2.8
Cotton	7.7	Corn for Silage	1.7
Tall Wheatgrass hay	7.5		

† Varietal differences exist with respect to salinity tolerance. Examples include Salado, Ameristand 801S and WL454HQ.RR.

Wheat for silage can also be grown under saline conditions, but water may not be available during its production cycle.

3) Determine other soil limitations to crop growth. Soil lime, for example, can induce iron deficiency in sensitive crops such as sudangrass, sorghum, and forage corn.

4) Determine leaching requirement from an irrigation water salinity assessment and attainable or target soil salinity level. The more tolerant a crop is to salinity, the less leaching of salts will be required in the short-term to maintain yield potential. Leached water is generally below the effective root zone of crops.

5) Know your available water holding capacity (AWHC). Available soil water for plant growth is primarily influenced by soil texture, salinity, and organic matter content. Water delivery to the field should provide water for the top 2 to 3 feet of soil plus any required calculated leaching requirement (LR). Salinity also reduces the amount of water available for plant uptake.

Texture with 1% Org. Matter	24" AWHC (acre inches)
Clay	2.90
Clay loam	3.30
Loam	3.38
Sandy Loam	2.36
Sand	1.06
Silty Clay Loam	4.06

Sodic soils should be avoided during years with little available water.

Selecting salt tolerant crops lowers the leaching requirement.

Low available water holding capacity soils require more frequent irrigation to keep up with crop water demand. ■

Additional Information on Saline Soils

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