BETTER CROPS WITH PLANT FOOD

1999 Number 2

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BETTER CROPS
WITH PLANT FOOD

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Our Cover: No-till planting. **Photo source:** Bob Elbert

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Information Agriculture Conference

SET FOR AUGUST 9-11, 1999

The popular Information Agriculture Conference series will continue with InfoAg99 scheduled for August 9, 10, and 11, 1999. Organized by the Potash & Phosphate Institute (PPI), Foundation for Agronomic Research (FAR), and Purdue University, InfoAg99 will take place at the Stewart Center on the campus of Purdue University, in West Lafayette, Indiana.

"The 1999 program will focus on adaptation of site-specific technologies and information systems related to crop production. Past conferences in 1995, 1996 and 1997 provided effective forums which brought together diverse groups in production agriculture. The upcoming conference will feature analysis and interpretation of data and its incorporation into comprehensive nutrient management planning and decision-making," said Dr. Paul E. Fixen, PPI Senior Vice President and conference planning coordinator. In one program track, 20 site-specific management guideline topics will be presented.

In addition to an agenda of expert speakers and workshop sessions for smaller groups, there will again be an exhibit area where companies and organizations can display new products and services in data management, analysis, and communications technology.

A communications showcase will feature educators demonstrating how interaction among farmer/dealer/landlord/banker can be improved to better use available resources for more profitable production. A "cyberfarm community" will demonstrate the potential of information technology.

The conference is expected to appeal to a cross-section of people in agriculture, including top farmers, fertilizer dealers, consultants, Certified Crop Advisers, farm managers, government agency personnel (particularly Natural Resources Conservation Service), university researchers, teachers, Extension specialists, and international participants.

Another key section of the program will highlight aspects of building a business around site-specific systems. Commerce experts will discuss service business opportunities for retailers and consultants. The CyberDealership Workshop returns with a fresh look at putting the pieces together for a business plan.

Also participating as sponsors of InfoAg99 are: AgriNews Publications; *Dealer Progress/PrecisionAg Illustrated*; Doane Agricultural Services; Environmental Systems Research Institute – ESRI GIS; *Farm Chemicals/Ag Consultant*; John Deere Precision Farming; United Soybean Board; and VantagePoint Network.

Registration fee to attend the conference is $350 per person for payment received by July 10, $450 thereafter.

For registration information contact:
Phyllis Pates, PPI
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655 Engineering Drive, Suite 110
Norcross, GA 30092
Phone: 770-825-8074
Fax: 770-448-0439
Email: bagerton@ppi-far.org

More information on registration procedures, exhibitor fees, hotel accommodations, and other details are available. Obtain current program and other updates about the conference at **www.ppi-far.org/infoag99**.

MISSOURI

Can Topsoil Thickness Help Determine Crop Phosphorus and Potassium Nutrient Needs?

By N.R. Kitchen, R.E. Spautz, and K.A. Sudduth

Research is evaluating the importance of topsoil thickness along with soil test results for predicting crop nutrient needs. Studies in Missouri have focused on phosphorus (P) and potassium (K) nutrition of corn and soybeans grown on claypan soils. Higher soil test levels of K are beneficial where topsoil is thin.

A premise of precision agriculture for variable-rate fertilizer application is that the soil's nutrient supplying capacity for crop growth is different for various locations within a field. In practice, this principle is applied by soil sampling at different locations within the field (such as sampling by soil type or grid soil sampling and mapping) and applying fertilizers as determined by the soil test results.

Another aspect of the crop nutrient pool that might also be quite different within fields is variation in the nutrient pool with soil depth. Typically, for immobile nutrients such as with P and K, soil samples are taken from the surface 6 to 8 inches...referred to as the plow layer. Early developers of soil testing programs found that with many soils, immobile nutrients accumulate near the soil surface. This fact along with the difficulty in deep soil sampling resulted in sampling strategies directed at and calibrated with the surface plow layer. If, for any given location within a field, nutrient levels vary greatly below that soil-sampled depth, soil test results may not be a good predictor of the soil's nutrient supplying capacity.

Previous work in Missouri has shown how soil electrical conductivity can be used to measure topsoil thickness for claypan soils (*Better Crops with Plant Food*, 1997, No. 4, pages 6 to 8). In this work topsoil thickness was defined as the soil depth from the surface to the high-clay Bt horizon. The topsoil is generally considered to be much more fertile than soil in the "clay-

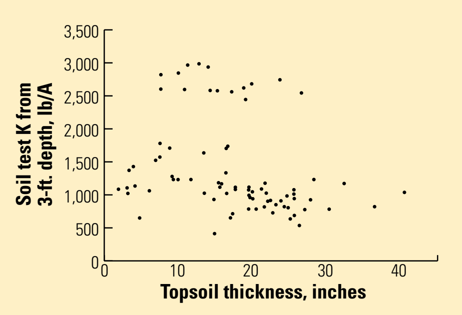


Figure 1. Soil test K accumulated over 3 feet of soil from 80 different locations spread over 16 Missouri claypan fields.

Claypan soil field where crop response to variations in topsoil and soil test P and K was studied. While the slope on this field is less than 2 percent, topsoil thickness varies from several inches to over 4 feet deep.

pan." Further, plant-available water capacity and air-space for root growth are poor in the claypan when compared to the topsoil. The question we considered with this claypan soil research was: Can a more accurate prediction of crop nutrient needs be made by using topsoil thickness along with soil test results? Two studies were conducted to help answer this question.

Topsoil Thickness and Soil Test P and K

In the first study, soil samples were taken from 80 separate locations within 16 claypan soil fields (3 to 6 locations per field) in north-central Missouri. At each field location four deep core sub-samples were taken within an area 10 ft. in diameter, divided in 6-inch increments to a depth of 3 ft., and analyzed using University of Missouri soil test procedures for plant available P and K (Bray P-1 and ammonium acetate extractable K). Topsoil thickness was also measured for each location.

Results showed that soil test K was greatest in the surface 6 inches of soil, but that at some locations subsoil K was also significant. Totaling the soil test K over the 3-ft. profile from these 80 locations illustrated how variable plant-available K can be (**Figure 1**). Some individual fields appeared to have significant subsoil K (upper group of points in **Figure 1** are mostly from three fields). While topsoil depth was a poor predictor of total K in the 3-ft. profile, there was a slight trend for soil test K to be less with increasing topsoil thickness. This trend may be the result of greater nutrient removal with deep topsoil since, for many years, deeper topsoil translates into greater plant-available water and grain production.

Topsoil thickness and sample depth were helpful in explaining differences in soil test P in the 3-ft. profile (**Figure 2**). Many locations with deep topsoil also had higher soil test P levels in the surface 6 inches of soil. Soil erosion and deposition downslope of sediment and soil organic matter (major sources of labile P) have contributed to topsoil thickness variations at these sampled locations. This landscape process helps explain why soil test P would be greater with deeper topsoil. Some locations with shallow topsoil showed increasing soil test P in the 24- to 36-inch depth. At these depths, the P is probably from iron (Fe)- or aluminum (Al)-P minerals since soil organic matter is very low in the subsoil. The root-restrictive nature of the claypan horizon probably limits crop use of this deeper, subsoil P.

Crop Response to Variations in Topsoil and Soil Test P and K

In a second study, 108 P and K response plots were established in 1996 at different topsoil-depth locations within a single field. Twelve months later each plot was soil sampled to a depth of 6 inches and analyzed for P and

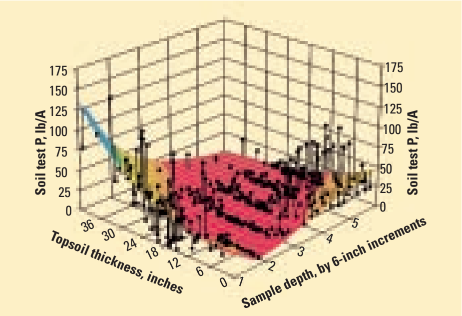


Figure 2. A response surface (R^2=0.44) of how sample depth and topsoil thickness affect soil test P. Results from 80 different locations spread over 16 Missouri claypan fields. Points are actual values, and lines from points show deviation from the response surface.

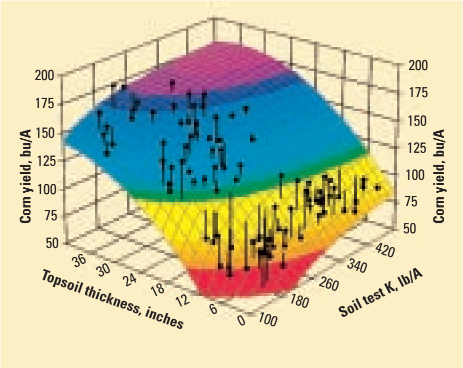


Figure 3. A response surface (R^2=0.77) of how soil test K and topsoil thickness affected corn yield. Points are actual values, and lines from points show deviation from the response surface.

K availability. Topsoil depth was also determined for each plot.

In 1996 and 1998, soybean yields ranged from 45 to 65 bu/A and were not affected by topsoil depth or levels of soil test P and K at the 0- to 6-inch depth.

In 1997, variations in corn yield were best explained with topsoil thickness, soil test K (**Figure 3**), and a significant interaction between these two factors. Because of dry conditions during late July and early August, stored soil moisture resulted in large yield differences. With only about 6 inches of topsoil, corn yield ranged from 40 to 60 bu/A. With 2 to 3 ft. of topsoil, yield was about 140 to 160 bu/A. The greatest positive benefit with increasing soil test K was where the topsoil was thin. Because plant K nutrition plays such an important role in water regulation and plant response to water stress, higher levels of soil-test K were needed in thin topsoil areas of the field.

With only one year and site of data showing this topsoil by soil test K interaction response, it is difficult to make an economic projection at this time. However, using the response relationship shown in **Figure 3**, we evaluated, at different topsoil thicknesses, the soil test K level when the rate of yield increase was only one-tenth of a bushel for every 1 lb/A increase in soil test K. Within the same field, the soil test K level to get this specified yield response varied by about 90 lb K/A.

These response values were then compared to the "desired soil test level" using current University of Missouri recommendations (**Table 1**). The University of Missouri recommended desired soil test level is determined using cation exchange capacity (CEC). We used CEC values from the plot areas for this comparison (column 3 of **Table 1**). With shallow topsoil, measured CEC was greater because the surface soil has more clay. That gave a higher desired soil test level. The range in variation in recommended "soil test K" was less than the range in response as shown in **Figure 3** and calculated in column 2 of **Table 1**. Thus, using CEC can help predict the need for a variable optimal soil test K level among areas of the field. However, as shown with these results, other information such as topsoil thickness might be more helpful in predicting the variability in crop K needs within fields. Additional research is being done on these plots to determine if crop K needs are being met by subsoil nutrients.

TABLE 1. Optimal soil test K levels from this study compared to current recommendations from the University of Missouri.

Topsoil thickness, inches	Soil test K level for specified yield increase[1], lb K/A	Average CEC from study plots, meq/100 g	University of Missouri desired soil test level[2], lb K/A
6	330	18	310
12	314	14	290
18	297	12	280
24	279	11	275
30	260	11	275
36	240	10	270

[1] Soil test K level for rate of yield increase of one-tenth of a bushel for every 1 lb/A increase in soil test K.

[2] Recommended desired soil test level for corn = 220 + 5 (CEC).

In the future, improved precision fertilization programs may require even more precision in the assessment of nutrients available for crops. This research is indicating that subsoil nutrients vary significantly and may play an important role in meeting crop nutrient needs. In some areas of the U.S., subsoil sampling is currently advocated to assess subsoil nutrients.

Dr. Kitchen is a Soil Scientist and Dr. Sudduth is an Agricultural Engineer, both with USDA-ARS, and Mr. Spautz is a Senior Research Specialist with the University of Missouri-Columbia.

Tomato Yield Variability Related to Soil Texture and Inadequate Phosphorus Supply

By G.S. Pettygrove, S.K. Upadhyaya, J.A. Young, E.M. Miyao, and M.G. Pelletier

Irrigation and soil physical management are often controlling factors in establishing processing tomatoes, preventing disease, and achieving high fruit yield and quality. Understanding spatial variation within individual fields may offer unique insights leading to more precise and, therefore, successful management.

Little research has been conducted on within-field spatial variability of irrigated crops grown in a Mediterranean climate such as exists in the Central Valley of California. Where the land is sufficiently level, gravity irrigation systems are common. In such systems, the soil serves as both a medium for root growth and a surface over which water is transported. Therefore, the relationship between soil properties and crop performance is more complex than in rain-fed and sprinkler-irrigated cropping systems.

Processing tomato is an important crop in California, with an annual gross farm value of $750 million, averaging $2,400 per acre. Irrigation and soil physical management are often the controlling factors in establishing the crop, preventing disease, and achieving high fruit yield and quality. What is the magnitude of spatial variation of tomato yield within individual fields? Is it possible to infer the causes of within-field variation from yield maps and conventional crop monitoring techniques. The research reported here was designed to answer those questions. It was supported by the University of California, the California Department of Food and Agriculture Fertilizer Research and Education Program, and the California Tomato Research Institute.

Yields and crop and soil conditions in two irrigated tomato fields of 106 and 78 acres were monitored at the Button & Turkovich Ranch in Winters, California in 1997. Soils are mapped as Capay silty clay, Marvin silty clay loam, and Rincon silty clay loam...all rated Class II due to slow permeability...and Brentwood silty clay loam and Yolo silt loam...both Class I soils. Each field contains areas of Class I and II soils. Fields have been graded to uniform slopes for furrow irrigation and have been in agronomic and vegetable crops for several decades. They were disked and bedded up on a 5-foot spacing following wheat harvest in 1996. Weeds were controlled during the 1996-97 winter. Processing tomatoes were either direct seeded (Field 1, 2/24/97) or transplanted (Field 2, 4/3/97) in a single row on each bed. The fields were managed by the grower using standard practices for the region and were harvested in late July (Field 1) and early August (Field 2).

Soil and plant tissue were sampled on a

Mechanical harvesting of processing tomatoes in the Sacramento Valley of California.

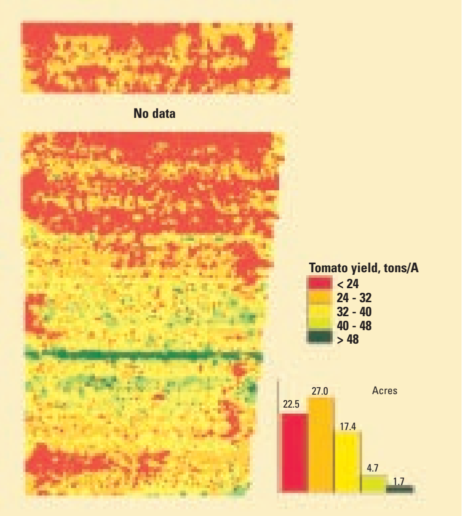


Figure 1. Yield map of processing tomato in Field 2. Field area is 78 acres. High yielding strip one-third of distance from southern boundary represents harvest of beds where field was "opened up" and plants from two beds were thrown onto adjacent beds to clear a lane for truck-trailer receiving harvested fruit.

Figure 2. Sand content (%, 0-6 inch depth) of soil in Field 2.

200 x 200-ft. grid spacing. Samples were obtained in a 15 x 15-ft. area at each grid intersection. Plant samples consisted of petioles of the fourth leaf from the top of 15 plants. Each soil sample was a composite of 10 to 15 cores (0-6 inch depth) collected from bed tops.

Yield was measured with a prototype weighing monitor/global positioning system (GPS) mounted on one of the grower's mechanical harvesters which straddles a single row of tomatoes. Spacing between adjacent yield points in the final data set ranged from 10 to 40 feet in the direction of travel. Yield data were converted to a 30 x 30-ft. grid using inverse distance squared weighting of the nearest 12 neighboring data points. All data were entered in ArcView geographic information system (GIS) software.

Mean fruit yields of the two fields were 35.3 ton/acre (Field 1) and 26.9 ton/acre (Field 2). Even though average fruit yields of the two fields were quite different, yield distributions were similar. The least productive 25 percent of the total area in each field yielded 71 to 75 percent of the field average and only 55 to 57 percent of the most productive 25 percent of the total area.

Both fields were harvested with more than one machine. There was more complete coverage by the harvester with the yield monitor in Field 2, allowing examination of yield spatial pattern in greater detail. Yields (**Figure 1**) were lowest in areas of the field with slowly permeable Capay silty clay soil located mainly in the northern half of the field and corresponding to the areas shown in **Figure 2** with lower sand content. Yields were generally higher in the better drained silt loams and loams in the southern half of the field. However, yield in the coarsest-textured southwest corner of the field was relatively low, probably due to under-irrigation.

Such irrigation-induced variability is difficult to avoid in gravity-irrigated systems. If the irrigator had used a longer "set" (i.e., left the water on longer) to accommodate the coarsest-textured soil, the crop would undoubtedly have suffered from prolonged saturated conditions in the areas of the field having finer-textured, less permeable soils. Some possible "precision ag" solutions to this would be (1) apply one or more extra irrigations to the portion of the field with coarser-textured soils, (2) convert the whole field to trickle irrigation, or (3) change to more closely spaced furrows and irrigate on a skip-furrow basis in the poorer-drained areas. Trickle irrigation systems are expensive to install and maintain and have not worked well on the heavy "cracking clay" soils on this farm, and the other two solutions involve unknown, but likely significant, labor and management costs.

In Field 1, soil test P levels were well above the critical level for tomatoes of 15 parts per million (ppm) sodium bicarbonate extractable. In contrast, in Field 2, both plant tissue and soil analysis indicate that the grower's knifed application of 100 lb P_2O_5/A in the fall seven months prior to transplanting of the tomatoes was not effective. Petiole phosphate at early- to mid-bloom in Field 2 ranged from very low to adequate and was related to yields (**Figure 3**). Soil available P of samples collected the previous year (during the wheat crop) was not as well correlated with tomato yield (**Table 1**). However, the mean value (7.7 ppm, sodium bicarbonate extractable) was well below the acceptable level for optimum yield. Both yield and petiole phosphate were related to soil texture (**Table 1**). Therefore, it is uncertain whether the direct cause of low yield was low soil P, or inadequate P uptake due to poor root development in areas with fine-textured soil where the crop was subjected to prolonged saturation.

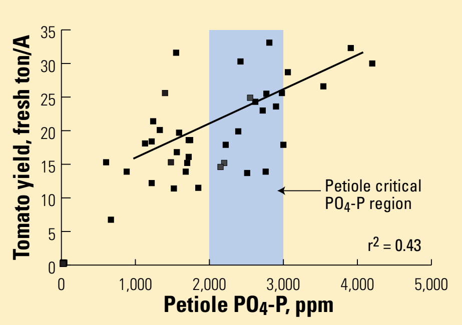


Figure 3. Tomato petiole phosphate level at early bloom vs. fruit yield in Field 2. Fertilizer P (100 lb P_2O_5/A) was knifed into beds in the fall seven months before tomatoes were transplanted in April 1997.

Summary

Tomato yield varied greatly within fields of 78 and 106 acres. Yield spatial patterns suggest the influence both of soil texture and cultural practices. In one field, inadequate P nutrition reduced yield, especially in areas of the field with heavy soil texture. Knifed P fertilizer applied seven months prior to planting apparently was not effective in supplying P to plants. A pop-up P application at planting time would likely be more effective.

In the same field, yield was also reduced in an area of coarse soil texture. The grower practice of optimizing irrigation timing for the finer-textured areas of the field likely resulted in under-irrigating the crop in the coarser-textured areas. Modifications to the furrow irrigation system design and operation are possible, though cost and manageability limitations must be addressed.

The authors are at the University of California, Davis, and UC Cooperative Extension, Woodland, CA. G.S. Pettygrove is Cooperative Extension Specialist, Land, Air & Water Resources, S.K. Upadhyaya is Professor, Biological & Agricultural Engineering, J.A. Young is Staff Research Associate, Agronomy & Range Science, E.M. Miyao is Cooperative Extension Farm Advisor, Yolo County, M.G. Pelletier is former Post Graduate Researcher, Biological & Agricultural Engineering.

TABLE 1. Relationship between tomato fruit yield and soil and plant characteristics in Field 2. Data collected from 79 grid points on a 200 x 200-ft. spacing.

	Yield	Midbloom petiole PO_4
	r	
Midbloom petiole PO_4	0.66	–
Late bloom petiole PO_4	NS	NS
Mid-bloom petiole NO_3	NS	0.53
Sand content	0.43	0.56
Clay content	-0.55	-0.65
Soil P[1]	0.49	0.41
Soil organic matter	NS	NS
Soil pH	NS	NS

r = coefficient of correlation. All significant at 1% level except where NS appears.

[1] sodium bicarbonate extractable

Potassium and Phosphorus Nutrition of Alfalfa: Preliminary Look at Impact on Yield Components and Root Physiology

By W.K. Berg, J.J. Volenec, B.C. Joern, K.D. Johnson, and S.M. Brouder

> A new Purdue University study is providing insight into the physiological and environmental factors interacting with phosphorus (P) and potassium (K) soil tests and fertilizer application on alfalfa yield and persistence.

In this study, roots are being analyzed for numerous physiological and biochemical attributes (including starch, sugars and proteins) thought to be critical for rapid growth after harvest and winter hardiness. In April 1997, a 3-acre site at the Throckmorton Purdue Agricultural Center was seeded to Pioneer Brand 5454 alfalfa. This site was selected for study because soil tests indicated low levels of soil P...5 to 15 parts per million (ppm)...and low to moderate soil K levels...50 to 120 ppm.

Following establishment, a factorial combination of P (0, 50, 100, and 150 lb P_2O_5/A) and K (0, 107, 214, 321, and 429 lb K_2O/A) fertilizer treatments was applied in split applications; one-half after the first forage harvest in May and the remainder after the last forage harvest in September. (First year applications were made in October of 1997 and again after the first cutting in May of 1998.) In 1998, four forage harvests were obtained when buds appeared on shoots, using a flail-type chopper. A sub-sample of shoots was obtained from each plot in order to determine mass per shoot, and shoots per unit area were calculated using the data for mass per shoot and forage yield per unit area. The relatively large 15 x 30 ft. plot size allows periodic root sampling to obtain information on plant population per unit area (persistence), and to acquire root samples for laboratory analysis.

Summary of Findings in 1998

Alfalfa forage yield increased significantly with increasing K applications (**Figure 1**). Initial soil K levels were slightly above the critical level required for alfalfa growth, but by Harvest 3 there was a K response. At the end of summer 1998, K deficiency symptoms were visible in some of the control plots where soil K levels were initially lowest. There was also a significant response of forage yield to P application. These findings represent only the first year of the study. It is anticipated that the differences will become more pronounced in succeeding seasons.

Increases in forage yield in response to P and K were generally associated with greater mass per shoot. However, control plots receiving no P or K fertilizer had more shoots per unit area than did plots provided P or K. The reduced competition for light, water, and other resources under P and K stress may allow plants to produce more shoots per unit area than is possible when P and K stimulate shoot growth.

In a new study, Purdue researchers are looking at physiological effects of P and K fertilization as related to alfalfa yield and persistence.

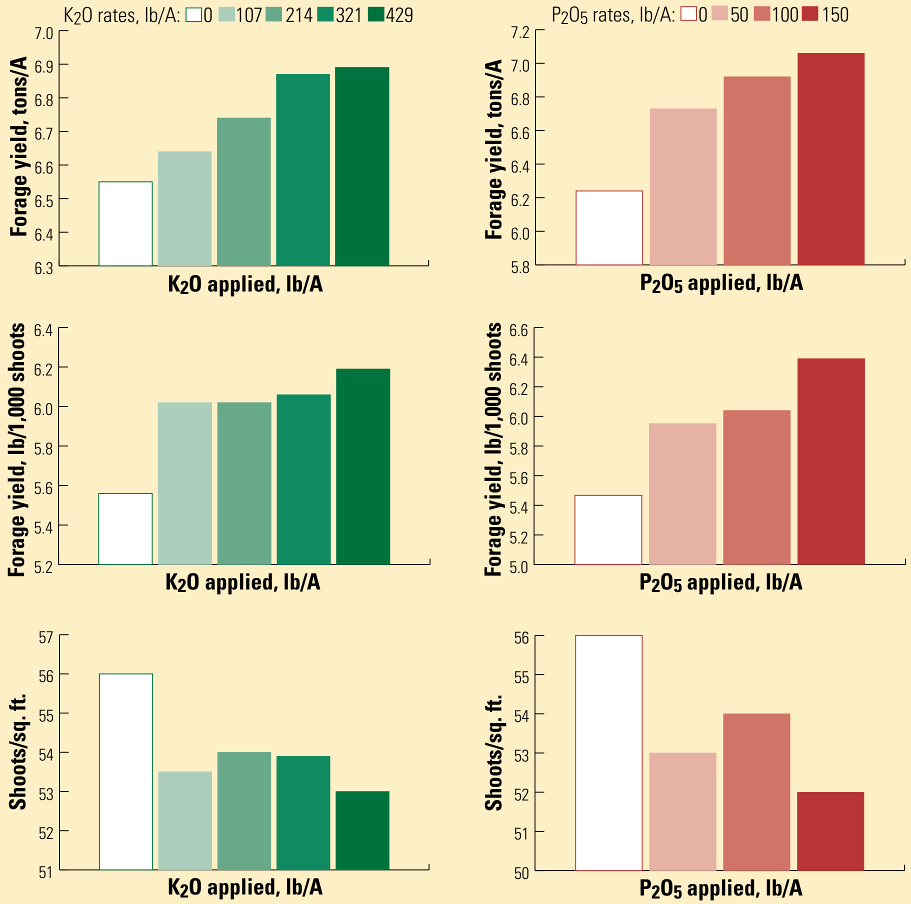


Figure 1. Forage dry matter yield, production per shoot, and stand density as influenced by P and K application for alfalfa. (Throckmorton Purdue Agricultural Center, 1998).

Despite having more shoots per unit area, the control plots generally yielded less forage than did the P and K fertilized plots because of the much larger shoots found on the latter.

Root analyses throughout this study will track effects of P and K levels on root sugar, starch, and protein contents. Stand counts will also be used to monitor effects on stand persistence and winter survival. This study is focusing not only on observations and yield, but also on the physiological basis for observed effects and how P and K influence the physiological processes. These findings represent only the first year of the study, and with continued nutrient removal in succeeding seasons, differences due to P and K application are expected to become more pronounced. We also expect to learn how P and K interact in determining agronomic performance of alfalfa.

Watch for further developments in this unique field study during coming years.

The authors are with Department of Agronomy, Purdue University, West Lafayette, IN 47907-1150. E-mail: jvolenec@purdue.edu

KANSAS

Best Management Practices to Minimize Phosphorus Runoff Losses from Cropland

By K.A. Janssen, G.M. Pierzynski, P.L. Barnes, and R.G. Meyers

Cropland runoff losses of P occur in particulate and soluble P forms. Particulate P is that associated with the sediment and organic particles in the runoff water. Generally, it accounts for most of the total cropland P being lost. It is the form of P in runoff from cropland which is the most difficult to discern as to its impact on water quality.

Research indicates that placement of fertilizer and manure containing phosphorus (P) deeper below the surface can be an important practice for reducing bioavailable P losses.

The soluble form of P is that which is dissolved in the solution phase of the runoff water. It is usually a much smaller quantity compared to the particulate P portion, but it is nearly all readily useable P and it can have an immediate and significant impact on water quality.

The key to preventing cropland P runoff losses is the control of runoff, the prevention of soil erosion, and the placement of P-containing fertilizers and manures to keep the P concentration in the near-surface soil zones as low as possible.

Cropping systems, such as no-till, which loosen very little soil at the surface and incorporate very little crop residue, are one of the most effective means for reducing soil losses. Many fields must use no-till to meet conservation compliance requirements. No-till provides essentially no opportunity for incorporating P fertilizers and manures. When these P containing materials are surface applied, P accumulates and remains in the near-surface soil zone. So while no-till might effectively reduce particulate P losses, it might accentuate soluble P losses. The solution is to place P fertilizers and manures deeper, below the critical interface zone (approximately the top one-inch of soil). Use of no-till on some soils and under certain environmental conditions can nearly eliminate runoff, while in other situations no-till may result in similar or increased

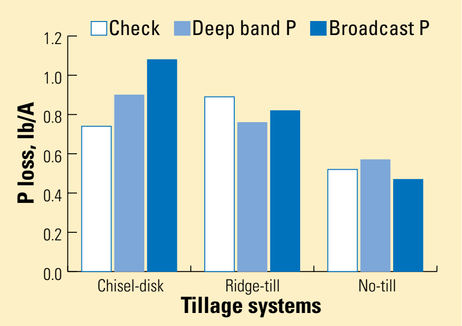


Figure 1. Particulate P losses as influenced by tillage and P placement, 3-year average, Kansas.

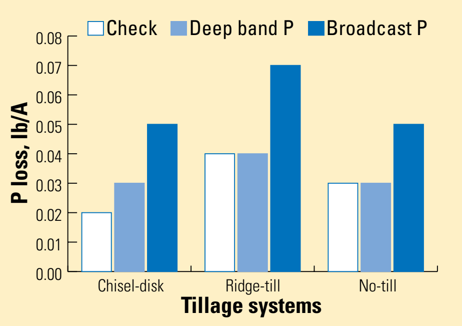


Figure 2. Bioavailable particulate P losses as influenced by tillage and P placement, 3-year average, Kansas.

runoff compared to tilled soils.

From a water quality perspective, there needs to be a balanced control of all forms of cropland P losses.

Kansas Research

Recent research in Kansas confirms the importance of injecting P fertilizers in conservation tillage systems and the incorporation of P fertilizers in tilled systems for best overall protection of surface water.

Research was conducted during 1995-1997 on a somewhat poorly drained, 1.5 percent sloped soil to measure the effects of tillage and P fertilizer placement on soil erosion and bioavailable P losses in runoff water. Bioavailable P is that which is useable by aquatic plants. It includes basically all of the soluble P in runoff water and a portion of the particulate P. Bioavailable P was measured by the FeO-strip method. The tillage and fertilizer systems evaluated were a chisel-disk-field cultivated system, a ridge-till system, and a no-till system. Fertilizer treatments were a P check, 50 lb P_2O_5/A surface broadcast, and 50 lb P_2O_5/A preplant, deep-banded (coulter-knifed at approximately 4-inch depth on 15-inch centers). Runoff from natural rainfall was collected during three grain sorghum fertilization and planting periods, 1995-1997.

Runoff and Soil Loss

Total runoff varied with rainfall, tillage systems, and years. Runoff, on average, was highest in ridge-till and no-till. Chisel-disk produced the least runoff. This was because tillage in the chisel-disk system loosened and dried the soil prior to some rainfall events which increased infiltration and reduced runoff. The amount of rainfall that ran off was 18 percent for the chisel-disk system, 32 percent for the ridge-till system, and 30 percent for the no-till system. Soil losses followed the pattern chisel-disk > ridge-till > no-till. On average, soil losses were 0.8 ton/A for chisel-disk, 0.6 ton/A for ridge-till, and 0.3 ton/A for no-till. Compared to chisel-disk, ridge-till lowered soil losses by 25 percent and no-till by 60 percent.

Phosphorus Losses

Losses of P in the runoff water also varied with rainfall, tillage systems, and years, but P fertilizer placement had the most effect. Particulate P losses on average were highest for chisel-disk and ridge-till and lowest in no-till (**Figure 1**). These differences generally parallel soil losses, since most of the particulate P losses were sediment-associated. The FeO-extractable P showed that roughly 5 percent of particulate P was bioavailable (**Figure 2**). Soluble P losses were highest with no-till followed by ridge-till and chisel-disk (**Figure 3**). Loss of soluble P in chisel-disk was least because of the incorporation of broadcast P. In ridge-till, where fertilizer P was only partially covered by shaving of the ridge at planting, soluble P losses were moderate. In no-till, where broadcast P remained exposed on the soil surface, soluble P losses were nearly six times greater than in the control. In contrast, deep-banded P increased soluble P losses

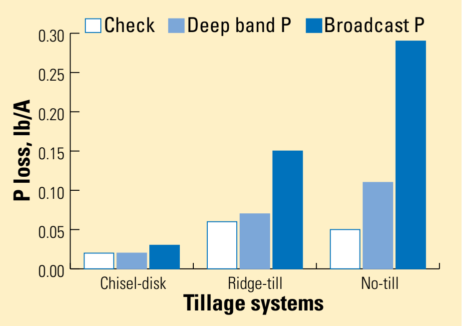


Figure 3. Soluble P losses as influenced by tillage and P placement, 3-year average, Kansas.

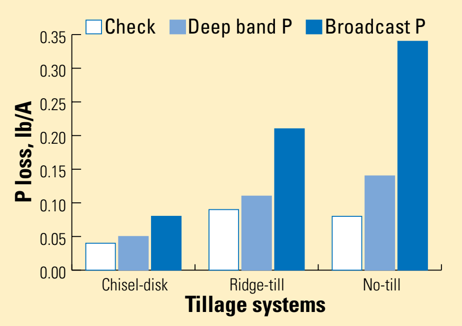


Figure 4. Total bioavailable P losses as influenced by tillage and P placement, 3-year average, Kansas.

only slightly over the control in all of the tillage systems.

Total bioavailable P losses (**Figure 4**) followed the same general pattern of loss as that for soluble P. This was because nearly all of the bioavailable P that was lost was in the form of soluble P. Under conditions with more soil loss, the percentage of contribution of bioavailable P from particulate P would likely have been greater. Nearly all of the bioavailable P that was lost occurred during the first couple of runoff events after the P fertilizer was applied. This pattern of P loss suggests that broadcast P should be incorporated before first runoff occurs.

The results of this study suggest that on fields where conservation tillage systems do not significantly reduce runoff, fertilizer P needs to be subsurface applied to prevent elevated levels of bioavailable P losses. In tilled systems, fertilizer P should be subsurface applied or incorporated before first runoff occurs.

The following are some cropland BMPs that can help minimize P losses in surface water runoff:

- subsurface apply or incorporate P fertilizer and manure prior to first runoff
- avoid surface soil buildup of soil test P
- periodically invert P-stratified soils
- use conservation tillage, terraces, contour farming, grass waterways, vegetative filter strips, cover crops, and other impoundments where appropriate to reduce runoff and soil loss.

Dr. Janssen, Dr. Pierzynski and Dr. Myers are with the Department of Agronomy, Kansas State University. Mr. Barnes is with the Bio & Ag Engineering Department, Kansas State University.

Research Notes

Quebec: Phytotoxicity of Banded Urea Amended with Triple Superphosphate and Potassium Chloride

Laboratory and field experiments were conducted to study the phytotoxicity of banded urea amended with triple superphosphate (TSP) and muriate of potash (KCl). In the laboratory, three soils were used to evaluate the effects of band placement of four rates of TSP and two rates of KCl on corn germination and growth compared to an unfertilized control. Field experiments were conducted on two soils, using two rates of urea and three rates of TSP, either compacted or blended. Results were as follows.

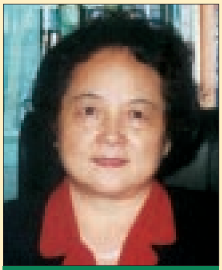
- In the laboratory, ammonia, nitrite and pH decreased with TSP and KCl, due to delayed hydrolysis of urea.
- Soil electrical conductivity (EC) increased with KCl, but was not affected by TSP.
- Corn growth decreased with increased soil ammonia concentration and EC.
- In the field study, corn germination increased with banded TSP and decreased with banded urea at day 10 after planting. No difference was found at day 20.
- Compacted mixtures of urea and TSP...compared to blended mixtures at the same phosphorus (P) rate... increased corn germination, growth, nitrogen (N) uptake, and yield.

Researchers concluded that compaction of urea and TSP might provide an effective way to improve the efficiency of banded urea for corn production.

Source: Agron. J. 90:734-739 (1998)

Robert E. Wagner Award Recipients Announced

Two outstanding agronomic scientists have been selected to receive the 1998-99 Robert E. Wagner Award by the Potash & Phosphate Institute (PPI). The Award encourages worldwide candidate nominations and has two categories...Senior Scientist and Young Scientist, under the age of 40. The recipient in each category receives $5,000 along with the award.


Prof. Zhu Zhonglin

Prof. Zhu Zhonglin, President, Sichuan Academy of Agricultural Sciences in Chengdu, China, was selected in the Senior Scientist Category. **Dr. Achim Dobermann**, Soil Nutrient Specialist, International Rice Research Institute (IRRI) in The Philippines, receives the honor in the Young Scientist division.

The Robert E. Wagner Award recognizes distinguished contributions to advanced crop yields through maximum yield research (MYR) and maximum economic yield (MEY) management. The Award honors Dr. Wagner, President (Retired) of PPI, for his many achievements and in recognition of his development of the MEY management concept...for profitable, efficient agriculture.


Dr. Achim Dobermann

Prof. Zhu is an internationally recognized soil scientist and has been engaged in research, demonstration and extension of a broad spectrum of soil science and fertilizer use activities in Sichuan province. Her studies on potassium (K) fertilizer use efficiency and balanced fertilization in south China showed that the lack of K was the major yield-limiting factor in agricultural production for the region. She was also involved in introduction of compound fertilizers...containing nitrogen (N), phosphorus (P), and K...which promoted balanced fertilizer use. This has played an important role in Sichuan's food production and improving farmer incomes.

Prof. Zhu edited the book titled *Compound Fertilizer Production and Application*. She has presented numerous scientific papers, addressed important international meetings, and received previous honors in recognition of her achievements. More recently, Prof. Zhu has been studying the relationship between soil erosion and plant nutrient loss from sloping lands in Sichuan. Soil and water conservation combined with balanced fertilization is crucial to this area in assuring high crop yields and profitable farming.

Dr. Dobermann is widely recognized for his scientific accomplishments in the area of soil fertility and integrated nutrient management. Since 1996, he has served as Soil Nutrient Specialist and Project Team Leader with IRRI, based in Manila, The Philippines.

His outstanding publication record in major international journals documents important contributions to basic understanding of soil nutrient dynamics in relation to plant availability and uptake and the use of geospatial statistical approaches to improve prediction of crop nutrient requirements.

Dr. Dobermann is leader of a major research project that seeks to quantify nutrient limitations and fertilizer requirements for irrigated rice on a dynamic, site-specific basis. The project involves extensive on-farm experimentation and active collaboration with about 40 scientists and 200 rice farmers from six Asian countries. One objective is development of a decision-support expert system to allow field-specific nutrient management recommendations that are more precise and profitable. He also led a major course for "training the trainers" which provides current information to rice researchers and extension workers in developing countries of Asia. BC

"J. Fielding Reed PPI Fellowships" Awarded To Four Graduate Students

Four outstanding graduate students have been announced as the 1999 winners of the "J. Fielding Reed PPI Fellowship" awards by the Potash & Phosphate Institute (PPI). Grants of $2,000 each are presented to the individuals. All are candidates for either the Master of Science (M.S.) or the Doctor of Philosophy (Ph.D.) degree in soil fertility and related sciences.

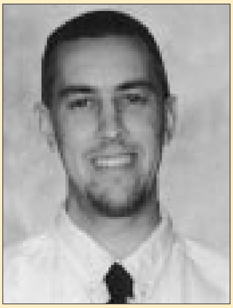
Beginning in 1980, a total of 120 students have now received the Fellowships. The four winners for 1999 are:

- **Kristofor R. Brye,**
  University of Wisconsin, Madison
- **James Scott Reiter,**
  Texas Tech University, Lubbock
- **Gregory J. Schwab,**
  Kansas State University, Manhattan
- **Ronald K. Young,**
  Kansas State University, Manhattan

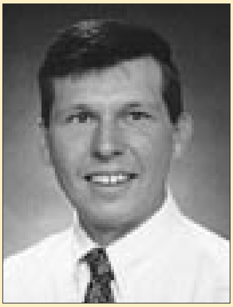
"Each year, we take this opportunity to recognize and encourage an outstanding group of graduate students in agronomic sciences," said Dr. David W. Dibb, President of PPI.

Funding for the Fellowships is provided through support of potash and phosphate producers who are member companies of PPI.

Scholastic record, leadership, and excellence in original research are among the important criteria evaluated for the Fellowships. Following is a brief summary of information for each of the 1999 recipients.

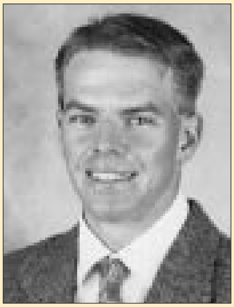


Kristofor R. Brye is a native of Middleton, Wisconsin. He received his B.S. degree from the University of Wisconsin, Stevens Point, and earned his M.S. degree at the University of Wisconsin, Madison. He is curently working toward a Ph.D. at that institution, his major area of study being soil science with a minor in environmental law. Mr. Brye was the recipient of the American Society of Agronomy Outstanding Soils Student Award in 1995 and he is listed in Who's Who Among Students in American Colleges and Universities. The title (tentative) of his Ph.D. dissertation is "Carbon and Nitrogen Budget Evaluation of Natural and Managed Ecosystems." Following graduate school, Mr. Brye plans to continue conducting research, concentrating on relevant environmental and soil science problems, integrating his scientific and research background with regulatory aspects of mitigating environmental contamination.



James Scott Reiter was born in Petersburg, Virginia. He received his B.S. degree at Virginia Polytechnic Institute & State University (VPI) and is currently studying for his M.S. degree at Texas Tech University, Lubbock. His major area of study is soil science. Mr. Reiter received several honors and awards as an undergraduate, including theAmerican Society of Agronomy Outstanding Senior Award in 1998. The title of his M.S. thesis is "Management Strategies for Maximizing Cotton Production in a Short Season Environment: Water:Phosphorus Interactions." Following his graduate work, Mr. Reiter would like to do research or become an Extension specialist, working with row crops forages. He plans to return to the southeast U.S. to pursue a career because he believes, "That area holds the most potential for increasing food supply as the world population continues to grow."

Gregory J. Schwab was born in Hamilton, Ohio. He completed his B.S. degree at Berea College, Kentucky, then earned an M.S. degree at Auburn University. He is currently in the fourth year of his Ph.D. program at Kansas State University, Manhattan. His major area of study is soil fertility. The title of his dissertation is "Management of Available Phosphorus Stratified Surface Soils in Reduced Tillage Cropping Systems." His research involves the evaluation of best management practices for available phosphorus (P) stratified surface soil in reduced tillage cropping systems. The results of his research will be used to help refine P fertilizer recommendations in Kansas and should show the advantages of subsurface applications in reducing P runoff in conservation tillage systems. Mr. Schwab plans a career as a soil fertility Extension specialist or as manager of a commercial soil testing laboratory.



Ronald K. (Kris) Young is a native of Wichita, Kansas. He received his B.S. degree from Kansas State University, Manhattan, graduating Summa Cum Laude. He is currently studying for his M.S. degree at Kansas State, his major area of study being soil fertility/nutrient management. Mr. Young has been the recipient of numerous awards and honors, including the American Society of Agronomy Outstanding Senior Award in 1998. He is also listed in Who's Who Among Students in American Universities and Colleges. The title of his thesis is "Site Specific N Management for Irrigated Corn in Kansas." His research has two primary focuses: increasing production profits and decreasing environmental risks. Following graduate work, Mr. Young plans to pursue a career in nutrient management, using his crop production background and experience with precision agriculture technologies.

The Fellowships are named in honor of Dr. J. Fielding Reed, former President of PPI. Dr. Reed passed away June 8, 1999. The Fellowship winners are selected by a committee of PPI scientists. Dr. A.E. Ludwick, PPI's Western U.S. Director, served as chairman of the selection committee for the 1999 Fellowships. BC

COLORADO

Water-Solubility of Zinc Fertilizer: Does It Matter?

By D.G. Westfall, M. Amrani, and G.A. Peterson

Colorado research indicates that total zinc (Zn) content of a fertilizer is not enough to determine its effectiveness for a crop grown on soils low in available Zn. A greenhouse study found that degree of water solubility is an important factor.

Zinc is an essential nutrient for plant growth and is commonly deficient in soils. While a Zn deficiency can severely impair crop growth and decrease yield, it can be easily and economically corrected by applying Zn fertilizers. Zinc sulfate ($ZnSO_4$) is the traditional Zn fertilizer, but many other sources are available, ranging from chelates to industrial by-products, such as those that contain zinc oxide (ZnO). Sulfuric acid (H_2SO_4) added to ZnO forms granular Zn oxysulfates. The greater the quantity of H_2SO_4 reacted with the ZnO (to form $ZnSO_4$), the greater the water solubility of Zn in the final fertilizer material. Zinc oxysulfates vary widely in their water solubility. In a greenhouse study, we evaluated the effectiveness of some commercial Zn granular fertilizer materials in correcting Zn deficiencies in soils testing low in plant-available Zn.

A Zn-deficient loamy sand soil with a DTPA soil test of 0.48 parts per million (ppm) Zn (low) and an organic matter content of 0.5 percent was used in this study. The soil initially had a pH of 5.1, but was limed to pH levels of 6.3 and 7.4 by adding 0.1 and 1.5 percent calcium carbonate ($CaCO_3$), respectively. Commercial granular Zn fertilizer materials used in this investigation were given different symbols, shown with some of their characteristics in **Table 1**.

Corn was grown in pots containing 12 lb of soil in a greenhouse. Zinc fertilizer granules were added to each pot, placed about 2 inches below the seed, at rates equivalent to 0, 5, 10, and 20 lb Zn/A. In order to evaluate these materials under conditions similar to those found in the field, we used the Zn sources in the physical condition found in the fertilizer bags. The granule mesh size was typical for each source. Materials were not ground or altered. Alteration of the physical granule characteristic of the fertilizer (grinding) would have artificially increased agronomic performance.

All six Zn sources were evaluated on the soil amended to a pH of 7.4. Only four were evaluated at pH 6.3 (**Table 1**). Above-ground corn forage was harvested 40 days after planting.

TABLE 1. Total Zn content and water solubility of Zn materials used in study.

Zn source	Zn fertilizer symbol	Total Zn, %	Water soluble Zn, %	Soil pH evaluated 6.3	Soil pH evaluated 7.4
$ZnSO_4 \cdot H_2O$	$ZnSO_4$	35.5	99.9		x
Zn oxysulfate	Zn20	20.4	98.3	x	x
" "	Zn27	27.3	66.4	x	x
" "	Zn40	39.9	26.5	x	x
" "	ZnOxS	37.7	11.0		x
" "	ZnOS	17.5	0.7	x	x

Visual Symptoms

Within 5 days after emergence, corn grown with no Zn and that receiving ZnOxS and ZnOS showed distinct Zn deficiency symptoms (**Photo 1**). Pronounced bands of chlorosis occurred on the leaves, starting near the leaf whorl. By the end of the growing period, one- to three-fold variations in plant height were observed among the fertilizer materials.

Growth response to $ZnSO_4$ at the four application rates is shown in **Photo 2**. A rate of 5 lb Zn/A from $ZnSO_4$ satisfied the Zn requirement of the plant. Similar results are shown for Zn20 in **Photo 3**.

Corn Growth

Dry matter production for the soil pH 7.4 study is plotted in **Figure 1**. Based on the growth response, three groups of granular Zn fertilizer materials can be identified: (1) ZnOS resulted in no significant response to Zn application; (2) Zn40 moderately increased dry matter production as Zn rate increased, particularly in the more acid pH 6.3 soil; (3) $ZnSO_4$, Zn20, and Zn27 increased dry matter production substantially. The very low agronomic effectiveness of ZnOS and ZnOxS is related to their lower water solubility and subsequent low Zn availability.

Photo 1. Zinc deficiency symptoms of corn ... bands of chlorotic tissue developing, starting at the whorl and progressing up the leaf. Within 5 days after emergence, corn plants that had received Zn fertilizers with low water solubility showed Zn deficiency symptoms.

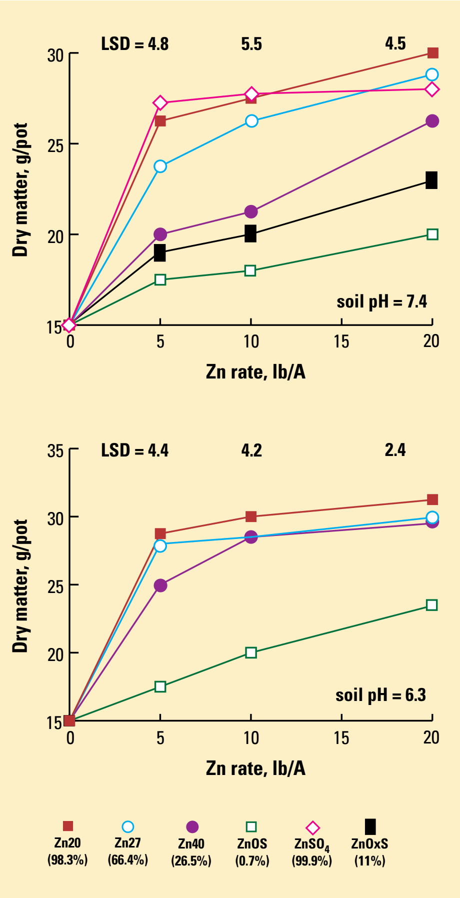


Figure 1. Corn dry matter production from six Zn fertilizers at soil pH 7.4 and four Zn fertilizers at soil pH 6.3. Fertilizers with low Zn water solubility showed limited effectiveness in increasing plant growth.

Water solubility appears to be the key to Zn availability for crops grown on soils low or deficient in Zn. This is substantiated by the

Photo 2. A high water soluble Zn fertilizer, $ZnSO_4$ (99.9 percent total water soluble Zn), supplied enough Zn at the 5 lb Zn/A rate to satisfy the plants' needs.

Photo 3. A zinc oxysulfate Zn fertilizer, Zn20 (98.3 percent total water soluble Zn), with a high water soluble Zn content, was able to supply enough Zn to satisfy the plants' needs.

fact that the increase in dry matter production was highly correlated with water-soluble Zn. Maximum dry matter production was related to percentage water solubility of the Zn fertilizer. An increase of 10 percent in Zn water solubility resulted in an increase in dry matter production of 5 percent. The increase in dry matter production for all Zn application rates as a function of percent water soluble Zn is shown in **Figure 2**. The higher the content of water soluble Zn in the fertilizer material, the lower the Zn application rate that is required to obtain maximum production.

Zinc Uptake

The ranking of the Zn fertilizers in relation to their ability to supply Zn to the plant was: $ZnSO_4$ > Zn20 > Zn27 > Zn40 > ZnOxS > ZnOS. This order matches the order of decreasing water-solubilities of Zn fertilizers, as shown in **Table 1**.

Conclusions

The long-term availability of these Zn fertilizer sources was not evaluated. It is not known if Zn from lower water soluble Zn sources would be more available in future years. If low water soluble materials do increase the soil Zn levels over time, the increase in Zn availability would be detected in the soil test levels in future years.

Our short-term greenhouse work conclusively showed that corn growth and Zn uptake were increased by increasing Zn application rates of fertilizers that are high in water-solubility. We suggest that granular Zn fertilizers should have water soluble Zn levels of about 50 percent to be effective in supplying adequate Zn levels to the current year crop. Knowing the total Zn content of a fertilizer is not enough to successfully determine the Zn fertilizer requirement

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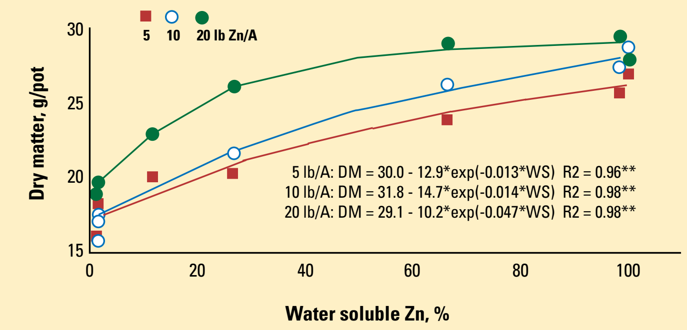


Figure 2. Effect of percentage water-soluble Zn in the fertilizer materials on dry matter production at three Zn application rates. Zinc fertilizers should have about 50 percent water soluble Zn content to be effective in correcting Zn deficiencies.

Soil Fertility and Fertilizers – Sixth Edition of Book Now Available

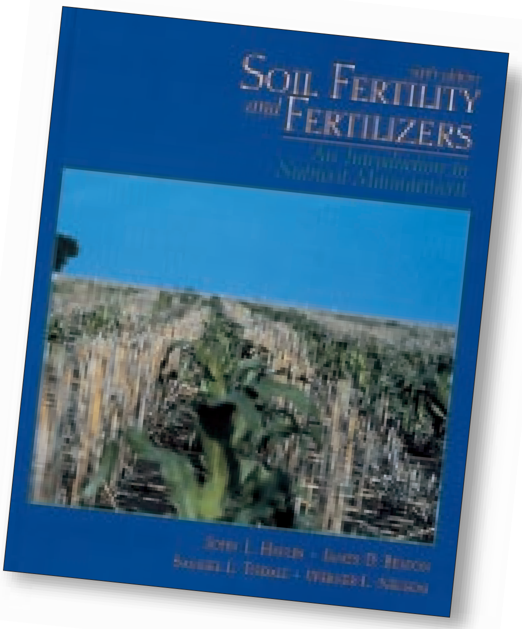
Long regarded as the outstanding book in its field, *Soil Fertility and Fertilizers: An Introduction to Nutrient Management*, is now available in its Sixth Edition.

The new publication reflects the rapidly advancing knowledge and technologies in plant nutrition and nutrient management. It is up to date, comprehensive, and readable in discussing the basic biological, chemical, and physical properties affecting soil fertility and plant nutrition.

Authors of the book are Dr. John L. Havlin, Dr. James D. Beaton, Dr. Samuel L. Tisdale, and Dr. Werner L. Nelson. Dr. Tisdale and Dr. Nelson, both now deceased, were authors of the first edition of the text. Dr. Beaton is now retired after a distinguished career in agronomic research and education. Dr. Havlin is Head, Department of Soil Science, at North Carolina State University, Raleigh. Contributions by Drs. Beaton and Havlin serve to further the book's effectiveness as a teaching tool.

First published in 1956, *Soil Fertility and Fertilizers* is considered the most widely read book ever written for this subject area. It develops a thorough understanding of plant nutrition, soil fertility, and nutrient management. The 499-page book contains 13 chapters covering a range of topics with reference to biological, chemical, and physical properties affecting nutrient availability.

Soil Fertility and Fertilizers, Sixth Edition (ISBN 0-13-626806-4), is available from Prentice-Hall, Inc., Upper Saddle River, New Jersey 07458. Cost of the book is $90.00 plus shipping. For single copy purchase in the U.S., call (800) 811-0912; in Canada, call (800) 567-3800. Additional information is available at: **http://www.prenhall.com**.



Water Solubility of Zinc Fertilizer...

(continued from page 20)

for a crop. Farmers need to know the degree of Zn water solubility of granular Zn fertilizers.

Dr. Amrani is former Visiting Scientist, now Research Associate with Alberta Agriculture, Agronomy Unit, Alberta, Canada. Dr. Westfall and Dr. Peterson are Professors, Department of Soil and Crop Sciences, Colorado State University, Fort Collins, CO 80523.

Acknowledgments – This research was supported by the Colorado State University Agricultural Experiment Station, CoZinCO Sales, and Agrium U.S. Inc. Appreciation is expressed to all sponsors of this research project.

KANSAS

Starter Fertilizers Containing Potassium for Ridge-till Corn and Soybean Production

By W.B. Gordon

Use of conservation tillage, including ridge-tillage, has increased greatly in recent years because of its effectiveness in conserving soil and water. In the ridge system, tillage at planting time is confined to a narrow strip on top of the ridge. The large amount of residue left on the soil surface can interfere with nutrient availability and crop uptake.

This research showed that starter fertilizer can increase corn and soybean yields, even when soil test phosphorus (P) and potassium (K) levels are high or very high. However, placement and K source determined the overall effects of starter fertilizer.

Starter fertilizer applications have been effective in enhancing nutrient uptake even on soils high in available nutrients. Many producers favor in-furrow applications of starter fertilizer due to low initial cost of planter-mounted application equipment and problems associated with knife applications in high residue situations.

Field experiments were conducted at the North Central Kansas Experiment Field near Scandia, on a Crete silt loam soil (fine, montmorillonitic, mesic Panchic Arguistoll) from the spring of 1997 to the fall of 1998. Soil tests in the corn experimental area showed that initial soil pH was 6.4; organic matter was 2.4 percent; Bray 1 P and exchangeable K in the top 6 inches of soil were 43 parts per million (ppm; high) and 380 ppm (very high), respectively. In the soybean area, soil pH was 6.5; organic matter content was 2.2 percent; Bray 1 P was 45 ppm (high), and exchangeable K was 350 (very high). The experimental design was a randomized complete block with three factors.

Both the corn and soybean tests included liquid starter fertilizer (7-21-7) made with two K sources applied either in furrow or 2 inches to the side and 2 inches below the seed (2x2) at planting. The two sources of K were sulfate of potash (SOP) and muriate of potash (MOP). Liquid 7-21-7 fertilizer was made using ammonium

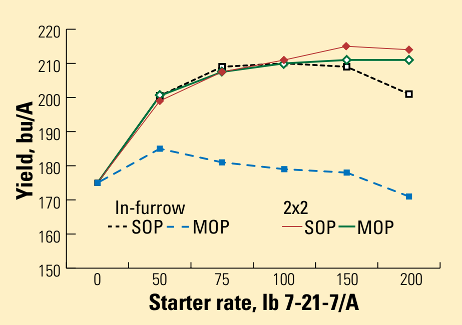


Figure 1. Effect of starter (7-21-7) placement, rate, and potassium source on corn yield.

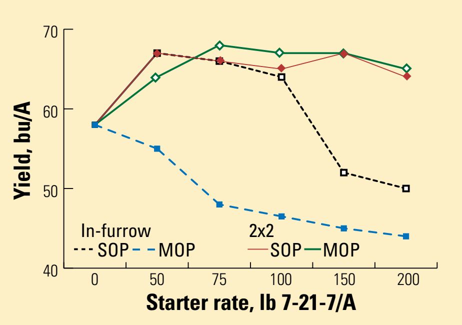


Figure 2. Effect of starter (7-21-7) placement, rate, and potassium source on soybean yield.

polyphosphate (10-34-0) and either SOP or MOP and was applied at 50, 75, 100, 150, and 200 lb/A.

A no starter check was also included. Sulfur (S) was balanced so that all plots received the same amount. Nitrogen (N) as 28 percent urea ammonium nitrate (UAN) was balanced on all corn plots to give a total of 200 lb/A. The soybean experiment received no additional N. Corn was planted in late April both years, at 32,000 seed/A. Soybeans were planted in mid-May at the rate of 200,000 seed/A. Stand counts were taken 2 weeks after emergence.

Results

Starter fertilizer increased yields of corn and soybeans despite high levels of soil P and K, except where excessive rates were applied in-furrow. Data illustrating the influence of starter rate, placement, and K source on corn and soybean yield and plant population are shown in **Figures 1** and **2** and **Table 1**.

In the corn experiment, starter fertilizer containing MOP applied in-furrow at the 50 lb/A rate reduced plant population by 4,493 plants/A and grain yields by 16 bu/A compared to the same rate applied in-furrow as SOP. Corn yield was reduced 31 bu/A when starter fertilizer containing MOP was applied in-furrow at 200 lb/A as compared to the same rate of SOP. When fertilizer containing SOP was placed in-furrow with corn seed, no population or yield reduction was seen except at the 200 lb/A rate where there was a 2,432 plant/A stand loss and a 12 bu/A yield reduction compared to the 2x2 placement. Although application of starter fertilizer at the 50 lb/A rate containing MOP increased yields over the no starter check, yields were still 16 bu/A lower than those when the same rate of MOP was applied 2x2.

TABLE 1. Effect of starter rate, placement, and potassium source on corn and soybean plant population 2 weeks after emergence.

		Placement			
		In-furrow		2 x 2	
	Rate	Potassium source			
	7-21-7	SOP	MOP	SOP	MOP
Crop	lb/A	plants/A, thousand			
Corn	0	31.3	31.3	31.3	31.3
	50	31.4	26.9	31.3	31.3
	75	31.3	25.1	31.4	31.3
	100	31.3	24.1	31.2	31.3
	150	31.0	24.6	31.2	31.2
	200	28.9	23.9	31.3	31.3
Soybeans	0	197	197	197	197
	50	196	160	198	198
	75	196	158	198	198
	100	192	152	198	198
	150	154	142	199	197
	200	152	139	198	197

The overall effect of rate, placement, and K source on corn yield is shown in **Figure 1**.

When starter fertilizer containing MOP was placed in-furrow with soybean seed, yields and plant populations were reduced regardless of rate. Yields and populations of soybean declined when in-furrow rates of starter fertilizer containing SOP exceeded 100 lb/A. Placement of starter 2x2 had no adverse effect on soybean yield with either K source. **Figure 2** illustrates the effect of starter rate, placement, and K source on soybean yield.

Conclusions

Starter fertilizer increased corn and soybean yield even though levels of soil P and K were high and very high, respectively. Placing starter fertilizer away from seed in a 2x2 placement was safe at the highest rates of application, regardless of K source. However, there are hazards associated with in-furrow placement of starter fertilizer containing MOP and SOP at higher rates. In general, salt injury from SOP proved to be less than MOP when applied in-furrow. Understanding the potential for damage from fertilizer placed in contact with seed is critical in achieving the maximum benefits of starter fertilization.

Dr. Gordon is with Kansas State University.

OKLAHOMA

In-Season Prediction of Yield Potential in Winter Wheat

By W.R. Raun, G.V. Johnson, M.L. Stone, J.B. Solie, W.E. Thomason, and E.V. Lukina

Nitrogen fertilization rates in cereal production systems are usually determined by subtracting soil test N from a specified yield goal-based N requirement. In general, the yield goal represents the best achievable yield in the last 4 to 5 years. This method of determining N fertilization rates has gone largely unchanged over the last 25 years.

Researchers are studying techniques for predicting wheat grain yield potential as a method for refining top-dress nitrogen (N) rates.

Our work has focused on predicting wheat grain yield potential using in-season spectral measurements collected from 10 sq. ft. areas between Feekes growth stages 4 and 5 (early jointing). At two locations where wheat was planted at different times, a modified normalized difference vegetative index (NDVI) was determined from multi-spectral reflectance measurements under daytime lighting.

$$\text{NDVI} = \frac{[(\text{NIR down/NIR up}) - (\text{Red down/Red up})]}{[\text{NIR down/NIR up}) + (\text{Red down/Red up})]}$$

In-season estimated yield (INSEY) was computed using the sum of NDVI at Feekes 4 and 5, divided by the growing degree days over that same time period.

$$\text{INSEY} = \frac{(\text{NDVI Feekes 4} + \text{NDVI Feekes 5})}{\text{Growing Degree Days}}$$

Grain yield was determined from the same plots where spectral reflectance readings were recorded during the growing season, and regression analysis was used to evaluate various relationships.

INSEY versus Grain Yield

The relationship between wheat grain yield and INSEY computed from spectral reflectance readings collected at Feekes growth stages 4 and 5 is illustrated in **Figure 1**. Because NDVI was known to be correlated with plant biomass, the sum of NDVI at any two early physiological stages was expected to be an indicator of forage yield and growth rate and is likely to be correlated with potential yield. The use of growing degree days in the computation of INSEY allowed us to consider both growing conditions and time (between the readings) and, thus, the influence of growth rate.

The 1998 growing season was unique since adequate moisture was present at planting and continued throughout the growing season. Only limited moisture stress was present, and both sites received timely rainfall near flowering. For this reason, yield and yield potential were expected to be similar, and thus INSEY was highly correlated with grain yield. In general, we would not expect the INSEY index to be highly

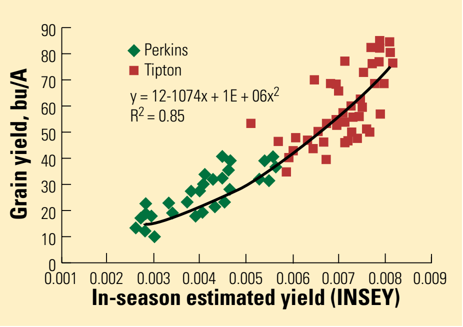


Figure 1. Relationship between INSEY computed from NDVI at Feekes growth stages 4 and 5, divided by growing degree days and observed grain yield, Perkins and Tipton, Oklahoma, 1998.

correlated with grain yield in all growing seasons since so many factors can negatively impact the wheat crop from Feekes 4 to maturity. However, our interest was in developing a yield goal parameter that was "seasonal-sensitive", intrinsic, and that would more accurately reflect yield potential likely to be realized in that season. If growth was poor from planting to Feekes 5, it is unlikely that a high yield potential would be realized. Similarly, if growth was excellent from planting to Feekes 4, but declined from Feekes 4 to Feekes 5 (drought, frost damage, etc.), yield potential would be expected to be lower.

In-season estimates of yield potential need to be viewed as refined estimates of yield goal. We are presently evaluating topdress N fertilization rates based on the in-season estimate of yield potential. Nitrogen fertilizer rates are estimated using the following equation:

$$\text{N rate} = \frac{[(\text{Predicted grain yield x \% N in the grain}) - (\text{predicted forage N uptake at Feekes 5})]}{0.70}$$

Predicted grain yield was estimated from INSEY, percent N in the grain was obtained from average values associated with winter wheat at different yield levels (higher percent N at low yield and lower percent N at high yield), and predicted forage N uptake at Feekes 5 was based on the published relationship with NDVI. This method is aimed at increasing yield (recognizing the need for increased N rates in areas with increased yield potential) and N use efficiency (decreased N applied where forage N uptake was already high). Our work assumes that the production system allows for in-season application of fertilizer N and that failing to apply preplant N has no adverse effect on grain yield. However, we recognize that using yield goals combined with soil nitrate-N (NO_3-N) testing remains as one of the more useful tools in establishing fertilizer N rates when preplant fertilizer N application is the only option.

If accurate estimates of yield potential are to be realized, these estimates will be needed at resolutions (10 sq. ft.) where differences in soil test parameters are found. If a coarser resolution (>100 ft.) is used, the variation in yield potential will be masked by averaging, and benefits that may be realized in treating the variability can be lost. In summary, the use of INSEY offers an alternative method of refining topdress N rates by basing N fertilizer need on in-season prediction of yield potential.

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Research Notes

California: Nickel – A Micronutrient Essential for Higher Plants

Research has established nickel (Ni) as an essential element for cereal crops. Using barley, the researchers satisfied the criteria of essentiality that (1) the plant cannot complete its life cycle without Ni and (2) no other element can substitute for it. They report: "Under Ni-deficient conditions, barley plants fail to produce viable grain because of a disruption of the maternal plant's normal grain-filling and maturation processes that occur following formation of the grain embryo. Since Ni was previously shown to be essential for legumes in unrelated research, it is concluded that Ni is essential for growth and reproduction of all higher plants.

Various researchers have shown that Ni deficiency affects plant growth, plant senescence, nitrogen (N) metabolism, and iron (Fe) uptake and may play a role in disease resistance. Nickel is the first micronutrient to be discovered as essential since chloride (Cl) was added to the list in 1954.

Source: Brown, Patrick H., Ross M. Welch, and Earle E. Cary. 1987. Plant Physiol. 85:801-803.

CALIFORNIA

Potassium Requirements for Maximum Yield and Quality of Processing Tomato

By T.K. Hartz

California is the leader in processing tomato production, growing nearly 40 percent of world supply. The majority of fruit is processed into concentrated paste, but an increasing percentage is being used for products utilizing peeled fruit, either whole or diced. Important fruit quality attributes for paste production are soluble solids content (SS) and color of the blended product. Uniformity of color is more important for peeled fruit. Even a small area of poorly colored tissue is problematic.

> Maximizing the color of tomatoes for peeling clearly required greater potassium (K) supply than that required for maximum fruit yield.

Uneven ripening of processing tomato fruit is a common problem in California. The typical external symptom, called yellow shoulder (YS), is a ring of tissue around the stem scar that upon ripening remains yellow. Internal white tissue (IWT), which can occur throughout the fruit, is often severe enough to render affected fruit unsuitable for use in peeled, diced products. The occurrence of these disorders has been frequent, but unpredictable.

Potassium nutrition has often been linked to tomato fruit yield and quality, but its relative influence on tomato fruit yield and quality under typical California field conditions is less clear. Exchangeable soil K is generally high, commonly greater than 150 parts per million (ppm), a level which numerous field trials have shown to be adequate to achieve maximum yield. Factors other than K fertility (primarily irrigation management) predominately control fruit soluble solids.

To systematically determine the influence

TABLE 1. Correlation of soil and plant characteristics with tomato fruit quality attributes.

	Exchangeable soil cations, meq/kg			K activity	K/$\sqrt{Mg}$	K concentration, %	
	K	Ca	Mg	ratio[3]	ratio	leaf	fruit
Leaf K, g/kg	.25[2]	.01	-.14	.29[2]	.25[2]	–	.19[1]
Fruit K, g/kg	.54[2]	.33[2]	-.40[2]	.55[2]	.64[2]	.19[1]	–
Soluble solids, ° Brix	.23[2]	.19[1]	-.02	.20[1]	.24[2]	.28[2]	.09
Blended color	.02	.15	.00	-.02	.04	-.11	.09
Yellow shoulder, % of fruit	-.34[2]	-.05	.36[2]	-.38[2]	-.41[2]	-.22[2]	-.35[2]
Internal white tissue, %	-.33[2]	-.04	.30[2]	-.36[2]	-.38[2]	-.17[1]	-.32[2]
Total color disorders, %[4]	-.38[2]	-.07	.35	-.42[2]	-.45[2]	-.19[1]	-.38[2]

[1] and [2] Correlation significant at $p< 0.05$ or 0.01, respectively.

[3] $K/\sqrt{Ca + Mg}$, on a soil exchangeable meq/100 g basis.

[4] % of fruits expressing either YS or IWT.

of K nutrition on processing tomato quality, a survey of 140 tomato fields was conducted during 1996 and 1997. Fields were chosen to represent the geographical range of production in central California, a variety of soil types, and harvest dates from early July through late September. To minimize cultivar effects, all fields monitored were planted in either 'Halley' or 'Heinz 8892'. These cultivars represented nearly 50 percent of processing tomato production in California in 1997.

Composite soil (top 12 inches) and whole leaf samples (recently expanded leaves, at full bloom growth stage) were collected in each field. Soil was analyzed for ammonium acetate exchangeable K, calcium (Ca) and magnesium (Mg), leaf tissue for K, Ca, and Mg concentrations. Fruit samples were collected just prior to commercial mechanical harvest. A subsample of fruit was mechanically juiced and analyzed for SS (° Brix, by refractometer) and color. Remaining fruit were scored for the number showing YS or IWT. Yellow shoulder was evaluated externally, IWT internally on fruit cut longitudinally.

Exchangeable soil K and soil cation balance were correlated with the tomato fruit color disorders YS and IWT, but had little effect on other fruit quality factors (**Table 1**). Exchangeable K, whether expressed as meq/100 g or as K activity ratio ($K/\sqrt{Ca + Mg}$, on a milliequivalent basis), was negatively correlated with the incidence of both YS and IWT.

Exchangeable Mg was positively correlated with, while exchangeable Ca was unrelated to, the disorders. The soil $K/\sqrt{Mg}$ ratio was more closely correlated with the percentage of total color disorders (YS or IWT) than was either exchangeable K or K activity ratio. The practical significance of the relationship of soil cation balance and fruit color disorders was greater than the modest correlations would suggest. Fields with less than 0.7 meq/100 g exchangeable K showed a wide range of color disorder severities, with an average of 20 percent of fruit affected. Conversely, fields with greater than 0.7 meq/100 g exchangeable K averaged only 7 percent color disorders. Fields with soil $K/\sqrt{Mg}$ greater than 0.25 averaged only 4 per-

TABLE 2. Effect of soil amendment with gypsum and K on tomato fruit yield and quality.

Soil treatment	Total fruit yield, tons/A	Soluble solids, ° Brix	Blended color[1]	Color disorders, % of fruit YS	IWT	Total
Davis						
unamended control	47.1	4.5	22.8	9	8	13
2 tons gypsum/A	46.7	4.5	23.1	6	6	9
4 tons gypsum/A	45.3	4.5	22.5	5	5	8
200 lb K_2O/A	45.8	4.6	23.0	6	7	9
400 lb K_2O/A	48.9	4.5	22.9	7	5	9
4 tons gypsum + 400 lb K_2O/A	47.1	4.5	22.7	5	4	6
Contrasts						
gypsum vs. control	ns	ns	ns	**	ns	**
K vs. control	ns	ns	ns	*	ns	*
combination treatment vs. control	ns	ns	ns	*	*	**
Clarksburg						
unamended control	41.3	4.3	24.5	14	16	21
200 lb K_2O/A	42.2	4.4	23.3	8	7	11
400 lb K_2O/A	41.8	4.3	24.5	9	8	12
Contrast						
K vs. control	ns	ns	ns	ns	*	*

[1] Dimensionless unit, lower value indicates more intense red.

ns, *, ** Not significant, or significant at $p<0.05$ or 0.01, respectively.

cent color disorders. Potassium concentration in tomato fruit was more closely correlated with the soil $K/\sqrt{Mg}$ ratio than with exchangeable K. Exchangeable K was weakly correlated with fruit SS, but the slope of the regression relationship suggested that the impact of soil K level on SS was minor.

To document the connection between soil K status and tomato color disorders, two field trials were conducted in 1996. A site located at the University of California Vegetable Crop Research Center, Davis (UCD), was chosen which had a moderate K status (324 ppm extractable K, $K/\sqrt{Mg}$ ratio of 0.24). The other site, in Clarksburg, had much more limited K (137 ppm K, $K/\sqrt{Mg}$ of 0.08). At Davis, gypsum was fall-applied in replicated plots at 2 or 4 tons/A to dissolve with winter rains and displace some Mg. Prior to spring planting, K fertilizer at 200 or 400 lb K_2O/A was incorporated into the beds. At Clarksburg, replicated rates of either 200 or 400 lb K_2O/A were banded on the bed tops shortly after stand establishment, so the K would be moved into the root zone with the season-long sprinkler irrigation.

The fertilization trials confirmed the link between soil cation balance and the occurrence of YS and IWT (**Table 2**). At Davis, both the application of gypsum and K fertilization significantly decreased YS and total color defects. The combination of gypsum and K reduced total color disorders by 54 percent. Soil K application at Clarksburg significantly decreased IWT and total color disorders. Yellow shoulder and IWT incidence was higher at Clarksburg than at UCD, as the more adverse soil cation balance predicted. At neither site was fruit yield, SS, blended color, or leaf or fruit K concentration significantly affected by soil treatment.

The modest correlation between soil K and these color disorders in the field survey emphasized that soil extractable K is a useful, but imperfect, indicator of K availability. Factors such as soil physical characteristics (structure, compaction, aeration, etc.) and management practices that influence root density and function (most notably irrigation method, timing and volume) can affect K phytoavailability, since crop K uptake is a diffusion rate-limited process.

Dr. T. K. Hartz is shown examining plants in a California tomato field.

It is widely recognized that crop K uptake is affected by the activity of other soil cations. This study found that soil Mg had greater influence on crop K status, YS, and IWT than did soil Ca. Soil $K/\sqrt{Mg}$ ratio was the variable most closely correlated to fruit K concentration and the incidence of color disorders. Soil application of gypsum at the Davis site reduced color disorders, apparently by reducing exchangeable Mg, since soil exchangeable K was virtually unaffected.

The field trials showed that high levels of amendment may be required to substantially reduce fruit color disorders. This would particularly be true of soils with high K fixation capacity. Since no yield advantage would be expected if a soil had greater than 0.3 meq/100 g exchangeable K, it would be cost prohibitive to amend problem soils unless a significant premium was paid for improved fruit quality for peeling.

Despite the uncertainty regarding factors other than K that contribute to YS and IWT development, it is clear that K plays a dominant role. Only two of the 45 fields with soil $K/\sqrt{Mg}$ greater than 0.25 had significant levels of color disorders. This relationship will allow the processing tomato industry to use routine soil testing to rank fields for the relative danger of encountering severe YS and IWT expression and to suggest appropriate soil amendment strategies. BC

Dr. Hartz is Vegetable Crops Specialist, Department of Vegetable Crops, University of California, Davis, CA 95616.

Why Plants Need Phosphorus

By D.G. Blevins

Healthy soybean leaves track the sun during the day in order to absorb a maximum amount of light, whereas leaves suffering P deficiency may turn their edges toward the sun in order to absorb minimum amounts of sunlight.

Phosphorus is an important essential macronutrient required by all plants for growth, development and reproduction.

There are many important biochemicals in plants that contain P. Phospholipids are the primary structural component of membranes that surround each plant cell and organelle. Inside the cell, genetic information in the form of DNA and RNA molecules contains P as an integral structural component. These important molecules form the genetic information in the plant and guide the synthesis of proteins that work inside cells.

Phosphorus (P) is involved in photosynthesis, seed formation, and numerous other plant functions.

Proteins

Once proteins are made, when and where they work may be regulated by events that again involve P. Much of the metabolism inside cells is controlled by phosphorylation or dephosphorylation of certain proteins in an important class of proteins called enzymes. The addition or removal of phosphate then becomes a key signaling mechanism for what is happening inside a plant cell. The source of phosphate for signaling events is ATP (adenosine triphosphate). Besides this role, ATP is also the major energy currency in the cell. This molecule contains high energy phosphate bonds, which store and supply energy for cellular functions.

Photosynthesis

One of the keys to "life on earth" is the ability of plants to harvest energy from sunlight and trap it in the form of high energy phosphate bonds, to ultimately build carbohydrate molecules in the process of photosynthesis. Photosynthesis in plants involves P in many ways. Sugars made early in this process are mainly triose phosphates and hexose phosphates. Phosphate must also enter the chloroplast in order for triose phosphates to get out of the chloropast for use in other parts of the cell and in other plant parts. This phosphate/triose phosphate exchange reaction is critical for proper movement of sugar made in photosynthesis. In fact, in soybeans that are deficient in P, small sugars cannot exit chloroplasts properly. These sugars then accumulate and form large starch crystals which eventually cause structural damage to chloroplasts and shut down photosynthesis.

Water Movement

One of the most striking features of plants is their ability to move water in the xylem tissue. Xylem tissue is like an open piping system where water and nutrient elements move from roots to leaves. Water flow up the xylem tissue is very responsive to P and increases with high levels of P nutrition.

The control of the activity of proteins in plants by phosphorylation or dephosphorylation is of critical importance in many plant processes. Several proteins have unique structures that form gated channels through plant membranes, and these channels open and close depending on whether or not they are phosphorylated. These gated channels control, among other things, mineral and water transport in plants.

An adequate level of P nutrition has been found critical for proper magnesium (Mg) and calcium (Ca) uptake by roots and translocation up the xylem to leaves. The flow of Mg, Ca, and water up the xylem may be dependent upon availability of the high energy currency, ATP. With high levels of ATP, more P would be available for phosphorylation reactions opening Mg, Ca, and water channels in plant cells. More work needs to be done on specific channels in plant roots to determine their responses to the level of phosphate nutrition and ATP concentration in cells.

Photo source: Lauer and Blevins

Soybeans grown with adequate P nutrition (left) can rotate their leaves during the day to maximize interception of sunlight. With inadequate P nutrition, soybean plant leaves may have edges turned toward the sun and absorb minimal amounts of sunlight.

Seeds

During the late stages of plant reproductive growth when young seeds are being formed, P is remobilized from older leaves and moves into developing seeds. This makes a lot of sense, because seeds will contain important genetic information in the form of DNA. Phosphorus in seeds is also stored in phytic acid molecules. Each molecule of phytic acid contains six carbon atoms and six P atoms, and each of the P atoms has a negative charge. Therefore, the entire molecule contains six negative charges which can attract positively charged cations like potassium (K), Mg, Ca, copper (Cu), zinc (Zn), and iron (Fe). This is an effective way for seeds to store P and important cations for the next generation of plants.

Availability

Low soil level of plant-available P is a common condition around the world. Even though the total soil P may be high, the P is tightly bound to organic and inorganic soil components and is unavailable for uptake by roots. However, plants have developed many strategies for gaining access to bound P. These strategies include association with mycorrhizal fungi which attach to plant roots and develop hyphae that penetrate the soil, extract P, and then deliver it to the plant root in exchange for sugar. Some plants secrete organic acids, such as citric acid and malic acid, which form complexes with aluminum (Al) and Fe, releasing P for uptake by roots. Roots also secrete special enzymes like phosphatases, which break down organic forms of P in soil and make the P available for uptake by plant roots. Some plants have developed unique root architecture that helps them 'mine' P from the soil. These strategies are a few of the plant survival techniques that occur under stressful conditions.

Deficiency Symptoms

When plants are suffering from P deficiency, they have "hidden hunger" or they may show obvious visible symptoms. Visible effects of P deficiency are small, dark leaves and in some cases, purple coloration of stems and leaves. Roots of some plants suffering severe P deficiency may grow longer and skinnier than normal. This is fascinating since P deficient plants would not be equipped to handle a rapid rate of photosynthesis.

Dr. Blevins is with Department of Agronomy, University of Missouri, 1-87 Agriculture Bldg., Columbia, MO 65211. Phone: 573-882-4819, Fax: 573-882-1469, e-mail: blevinsd@missouri.edu

Research Notes

Tennessee: Foliar Feeding of Cotton – Evaluating Potassium Sources, Potassium Solution Buffering, and Boron

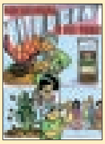
Research was conducted on two silt loam soils to evaluate four potassium (K) sources. A second study compared the effects of two foliar K sources...potassium nitrate (KNO_3) and potassium sulfate (K_2SO_4) solutions... buffered and unbuffered to two pHs on cotton nutrition and yield. A third study evaluated combinations of soil- and foliar-applied boron (B) and K.

Yields from the four K sources averaged 10 percent higher than the untreated check, and yields with KNO_3 were 4 percent higher than the other K sources. Buffering the two K solutions to a pH of 4 resulted in yields 10 percent higher than the check or unbuffered K solutions. Adding a surfactant to KNO_3 resulted in yields 5 percent higher than the check. Soil-applied B increased yields by 6 percent, and four foliar applications of B increased yield by 8 percent. Four foliar applications of B plus K increased yields by 13 percent.

Researchers pointed out that foliar K solution buffering and/or the inclusion of foliar B are relatively inexpensive ways of boosting yield response. Based on test results obtained, such treatments should return 8 to 10 times product costs.

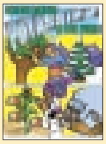
Source: Agron. J. 90:740-746 (1998)

Educating the Next Generation



Understanding Nitrogen in Our World

Understanding Phosphorus in Our World



Understanding Potassium in Our World

How we take care of the soil is important to our lives. A knowledge of what is best for the soil, what is best for the plants, and what is best for the world around us is a necessary part of everyone's education. The Potash & Phosphate Institute (PPI) and the Foundation for Agronomic Research (FAR) have developed three 24-page books for fourth through eighth grade instruction featuring nitrogen, phosphorus and potassium. The reader is led on a journey to examine the major nutrients for an understanding of why each is important to plant and human health.

If you would like to talk with someone about using these books in a classroom, more information, or to place an order for *Understanding Nitrogen in Our World*, *Understanding Phosphorus in Our World*, and *Understanding Potassium in Our World*, please call 770-825-8076. The books are $1.50 each plus shipping.

Tomorrow –

The Way to Have a Better Tomorrow is to Start Working on it Today.

In my 86 years of fascination with life, I have been privileged to be a part of the greatest revolution in all history.

The 20th century saw unbelievable accomplishments in medical science, engineering, and transportation, miracles in computer technology, and, tragically, the development of instruments of war and destruction that could mean the devastation of the human race.

All of these I have seen and been a part of. They influence the lives of everyone today and are a constant source of wonder.

There is another revolution – one taken for granted by so many – the great changes in agricultural science and farming that enable us to feed the people of this world.

Few can visualize life on the farm at the turn of the century – horses and mules, grueling manual labor, no electricity, poor sanitation – and no money. Crop yields and farming practices were about the same as they had been for centuries. Even in the 1930s, changes had been slow in the South where I lived; yields of 15 bushels of corn and one-third of a bale of cotton were common – “too dry”, “too wet”, “poor soils”, “worms and bollweevils.” Agricultural scientists themselves had limited education and few resources. What a different panorama we see driving through the beautiful farmlands today.

Now as I see the end of my chapter on this earth, it is a thrilling experience to visualize the great discoveries that lie in the future – high yield, soil conserving, precision agriculture – today’s greatest challenge.

Editor’s Note: Dr. Reed passed away on June 8, 1999.

J. Fielding Reed

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Potash & Phosphate Institute
Suite 110, 655 Engineering Drive
Norcross, Georgia 30092-2837