BETTER CROPS
WITH PLANT FOOD

Fall 1992

Featured in this issue:
Phosphorus . . . for Profitable Crop Production

BETTER CROPS With Plant Food

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Contents

Our Cover: A close-up view of healthy grain sorghum. This issue features the role of phosphorus in reducing and overcoming stress in crop production. Photo by Dr. Larry Murphy.

R.L. Latiolais Elected Chairman, C. Steve Hoffman Vice Chairman of PPI and FAR Boards of Directors

RENÉ L. LATIOLAIS, President and Chief Executive Officer of Freeport-McMoRan Resource Partners (FRP), has been elected Chairman of the Potash & Phosphate Institute (PPI) Board of Directors. He will also serve as Chairman of the Foundation for Agronomic Research (FAR). C. Steve Hoffman, Senior Vice President-Sales, of IMC Fertilizer Group, Inc., is the new Vice Chairman of the PPI and FAR Boards.

"We are proud to have René Latiolais and Steve Hoffman assume their new leadership responsibilities with the PPI and FAR Boards," said Dr. David W. Dibb, President of PPI. "Our efforts in market development through agronomic science will benefit with the guidance of these well-respected, globally-oriented industry leaders."

Mr. Latiolais is also Executive Vice President and Chief Operating Officer-Agricultural Minerals, of Freeport-McMoRan Inc. (FMI). As a member of the Office-of-the-Chairman, he is involved in the worldwide activities of FMI in addition to his executive responsibilities with FRP, which owns Agrico and Freeport Sulphur companies. Mr. Latiolais serves on the Board of Directors of The Sulphur Institute, International Fertilizer Association, PhosChem, Inroads, LSU Foundation, Florida Council of 100, and Southern Baptist Hospital in New Orleans.


R.L. Latiolais

A 1965 chemical engineering graduate of Louisiana State University, Mr. Latiolais received business training through the Program for Management Development, Harvard Graduate School of Business Administration.

Mr. Hoffman, in his present assignment with IMC Fertilizer Group, Inc., is responsible for worldwide sales of potash fertilizers, phosphate rock materials and phosphate chemicals. He joined IMC's Industrial Chemicals Division in 1974. From 1975 to 1978 he was a Field Sales Representative and in 1978 was promoted to District Sales Manager. In 1982, he joined IMC's International Division as Manager, Latin America. He served as Vice President, Domestic Wholesale Marketing in 1989 and 1990.


C. Steve Hoffman

A native of Pittsburg, TX, Mr. Hoffman is a 1971 graduate of Stephen F. Austin State University with a bachelor of arts degree in business administration. He is currently on the Board of Directors of the Phosphate Chemicals Export Association, the Phosphate Rock Export Association and the Canadian Potash Export Association (Canpotex).

In other action of the PPI Board, **Mr. Charles E. Childers**, Chairman, President and CEO of the Potash Corporation of Saskatchewan Inc., was elected Chairman of the Finance Committee. **Mr. Robert G. Connochie**, former Chairman of the PPI Board, was named Chairman Ex Officio. **Dr. B.C. Darst** was promoted to Executive Vice President of PPI.

Dr. Darst, who also serves as President of FAR, announced the election of **Mr. F. Zane Blevins**, Marketing Director, Allied-Signal Inc., to the FAR Board. ■

Canola Needs Phosphorus

By Lloyd Murdock, Jim Herbek, and Tim Gray

Kentucky research has shown that canola is highly sensitive to phosphorus (P) deficiencies. Winter survival and high yields are keyed to the availability of adequate amounts of P.

CANOLA is a high quality, edible oil crop that shows promise in the U.S. due to increasing demand for the oil within this country. The crop has been grown in Canada for many years and much of the information about the crop has been adapted from Canadian research. However, most of that research has been with the spring types which are planted in the spring and harvested in the fall. Most of the canola varieties grown in the U.S. are winter types which are planted in the fall and harvested in early summer.

One of the important fertility components of a fall seeded crop is P, since canola grows much of the time under cool soil conditions and P affects seedling vigor. In an effort to learn more about P requirements, canola was grown on a soil with different soil test levels of P.

Design

A field study was conducted at the Research and Education Center at Princeton, KY, in 1990 and 1991 on a Tilsit silt loam soil with a fragipan at about 24 inches and a pH of 6.5. Canola was drill-seeded in a conventional tillage situation at optimum planting dates in the fall. Nitrogen (N) was applied to the canola at the rate of 120 lb/A in the spring.

The different soil test levels for P and potassium (K) were obtained by adjustments to the field site over many years. The soil test levels for P ranged from 10 lb/A (low) to over 60 lb/A (high). Each plot was sampled for P soil test levels prior to planting and again after harvest. Soil test levels of P were determined using a Mehlich III extractant. The canola crops were grown on the plots without the addition of any fertilizer P.

Results

Phosphorus nutrition proved to be very critical for canola growth, survival and yield. There was no visual effect of the different levels of soil test P on emergence. However, after emergence, all phases of growth were affected. Fall growth was greatly affected by the different levels of P available to the plants. It was obvious in plant height and size of each plant (**Table 1**).

Table 1. Effect of P soil test levels on canola plant height and percent ground cover.

P soil test, lb/A	Plant height, inches	Ground cover, %
10	1.5	17
25	2.3	32
45	2.8	47
60	3.3	53
80	3.5	67

Two months after planting (1990).

There was also an effect on winter survival. Only a few plants survived the winter at the lowest level of P soil test. This was an extremely dramatic effect. Although no plant counts were taken, it can be easily seen in the yields in **Figure 1**. The lower yields of canola at the 20 to 30 lb/A soil test level may also have been

Dr. Murdock is Extension Soils Specialist, Dr. Herbek is Extension Grains Specialist, and Mr. Gray is Agronomy Technician, all located at the University of Kentucky Research and Education Center at Princeton, KY.

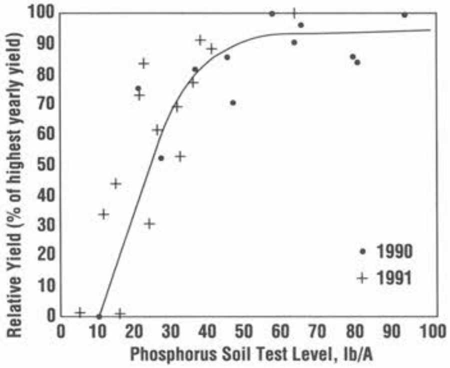


Figure 1. Phosphorus soil test levels have dramatic effects on canola yields (1990 and 1991).

partially related to some reduced winter survival. At higher soil test levels, the differences in yield were primarily related to spring growth and pod fill.

In 1990, maximum yield was obtained at a P soil test level of 60 lb/A, and 95 percent of maximum yield at 50 lb/A. In 1991, a maximum yield was obtained at a P soil test of 48 lb/A, and 95 percent of maximum yield at 40 lb/A. Combining the two years of data, it appears maximum yield level would be reached at a P soil test level of 50 lb/A and 95 percent of maximum yield at 45 lb/A.

These data indicate canola is very sensitive to P. At the lower soil test levels, canola showed a steep response curve. In fact, at P soil test levels of 10 to 15 lb/A or less, canola yields were extremely low or zero. Much of the sensitivity at low P soil test levels can be attributed to winter-hardiness. Although a high plant stand was achieved in the fall on the low soil test plots, few, if any, plants remained in the spring as compared to higher soil test level plots.

Summary

Our data indicate that canola is quite sensitive to P, even more so than wheat. Higher soil test levels of P were required by canola for maximum and 95 percent of maximum yield levels.

Phosphorus nutrition is important for canola winter survivability as indicated by low or zero yields and stands obtained with low soil test P levels. ■

SIX WEEKS after planting, fall growth differences are clear for canola in medium (left) and low (right) P soil test plots.

Kansas Research

Phosphorus Fertilization Relieves Stresses in Irrigated Corn Production

By Alan Schlegel

Providing adequate phosphorus (P) is a key part of corn production in the High Plains. This article provides some visual evidence of the P effects on development and maturity of irrigated corn.

PHOSPHORUS fertilization is essential for optimum production and economic returns from irrigated corn in western Kansas. As much as 50 percent of the P needs for corn are taken up after tasseling, emphasizing its importance in grain development.

PHOSPHORUS-DEFICIENT plants are often stunted and mature later than corn supplied with adequate P. This can make a significant difference in grain moisture content at harvest and influence overall farm crop profitability.

A long-term study has shown irrigated corn yield benefits from added P increased over time, from no initial effect to over 100 bu/A higher yields after 30 years of production. Without P fertilization, soil P levels declined from 17 to less than 10 parts per million (ppm) within 5 years. The addition of fertilizer P is necessary for both maintenance of soil test P levels and profitable yields.

Corn Phosphorus Deficiency Characteristics

Roots

- poorly developed root systems

Stalks

- stunted plants
- poor seedling vigor
- poor vegetative growth
- increased disease incidence

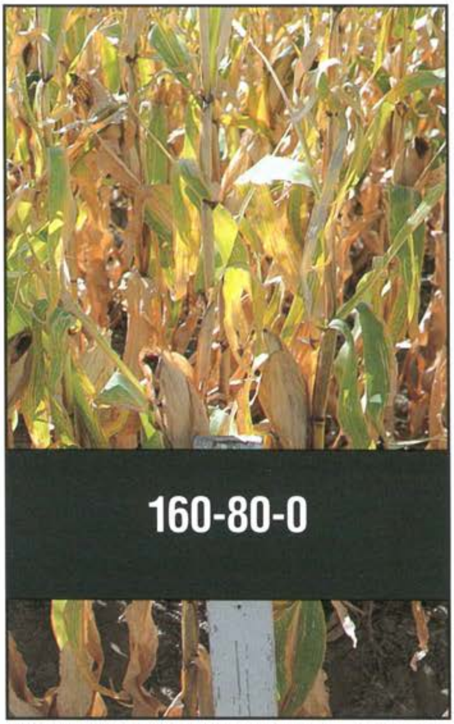
Leaves

- purple color developing on lower leaves, intensity varies with hybrid
- lower leaves of some hybrids appear bronze with purple edges

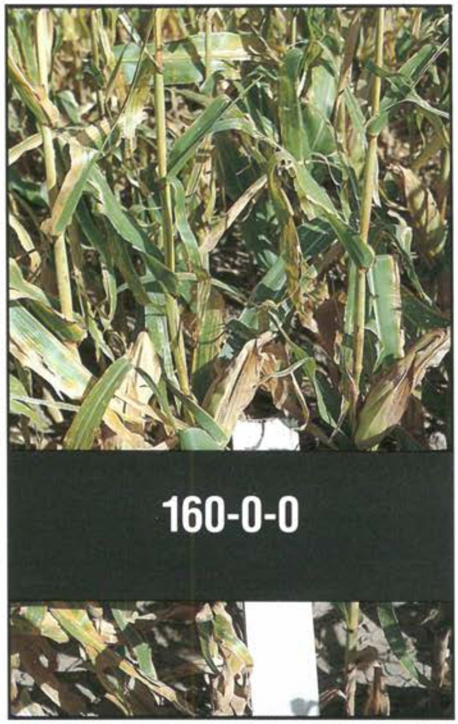
Grain

- poorly developed ears with irregular kernel rows
- slightly twisted cobs with barren tips
- delayed maturity
- reduced yields
- higher grain moisture at harvest

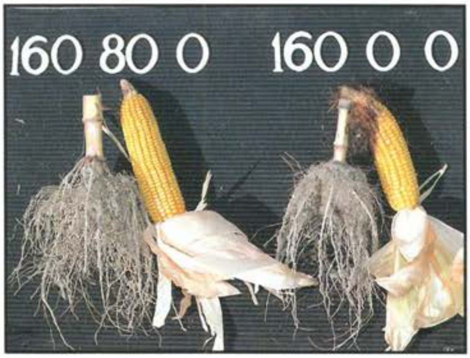
Dr. Schlegel is with the Southwest Research-Extension Center, Route 1, Box 148, Tribune, KS 67879.



WHEN adequate P is supplied, corn may mature 7 to 10 days earlier. Notice in this photograph that the shucks have already turned brown and plant drydown is advancing.



WITHOUT adequate P, plant maturity is significantly delayed. This photograph shows that P-deficient corn still has green leaves, stalks, and shucks.



PHOSPHORUS influences corn root development. When adequate P is provided, the plant produces a dense, fibrous root system. Without P, roots are plump and not as fibrous. Note how P affects ear fill and maturity. Without P, ears are slightly curved and poorly filled, with some immature silks still attached. Phosphorus also has a significant effect on stalk size and quality, as shown in the photograph.

Summary

Phosphorus fertilization is an important best management practice (BMP). It plays an important role in photosynthesis, respiration, energy storage, cell division, cell enlargement, and other plant processes. It promotes root growth and development, helps plants withstand disease, enhances uptake of other nutrients such as nitrogen (N) and increases water use efficiency. Phosphorus is also vital in seed formation and improves grain quality. Irrigated corn production in the High Plains has agronomic, economic, and environmental benefits from P fertilization. ■

Management of Acid, High Aluminum Soils for Wheat

By R.E. Lamond and D.A. Whitney

Kansas data indicate the importance of phosphorus (P) fertilization in managing acid, high aluminum (Al) soils for wheat when liming is difficult and expensive. Results of recent studies emphasize the importance of P placement with the seed and variety selection.

A SIGNIFICANT PART of the highly productive winter wheat area in south-central Kansas and north-central Oklahoma is being affected by acid, high exchangeable Al soil conditions. In 1990-91, 15 percent of the soil samples received at the Kansas State University Soil Testing Lab from the 12 county south-central Kansas area were pH 5.0 or less. Another 26 percent of the samples were between pH 5.1 and 5.5.

Kansas State and Oklahoma State researchers have documented the value of liming these soils. Dramatic wheat yield responses to lime on these soils are common. Recently, Oklahoma State researchers have established that band applications of P with the seed at planting can be an effective management technique on these soils when liming isn't possible. Apparently, the banded P ties up Al, allowing better early growth and development.

Kansas Research

Studies were established in Sedgwick County, KS, on a pH 4.7 soil which had 70 parts per million (ppm) KCl-extractable Al and Bray-1 P at 54 ppm (high). Three lime rates (0, 3,750, and 7,500 lb ECC/A), P_2O_5 (0, 40 lb/A broadcast, and 40 lb/A banded with seed), and two wheat varieties (Karl and 2163) were evaluated. The 7,500 lb ECC/A lime treatment was the full recommended rate. Karl is fairly sensitive to Al, while 2163 is somewhat tolerant to Al. Lime and broadcast P were applied and incorporated prior to planting.

Results

Shortly after emergence, visual differences began to appear. As the wheat started to break dormancy and begin

Table 1. Lime, P, variety effects on wheat yields.

Lime rate, lb ECC/A	P_2O_5 rate, lb/A	P placement	Wheat variety	Grain yield, bu/A
0	0	—	Karl	44
0	40	Broadcast	Karl	45
0	40	Band	Karl	58
0	0	—	2163	56
0	40	Broadcast	2163	59
0	40	Band	2163	59
3,750	0	—	Karl	51
3,750	40	Broadcast	Karl	50
3,750	40	Band	Karl	58
3,750	0	—	2163	61
3,750	40	Broadcast	2163	61
3,750	40	Band	2163	62
LSD(0.5)				

The full lime rate (7,500 lb ECC/A) had no significant effects on yield of either variety.

Dr. Lamond and Dr. Whitney are Professors of Agronomy, Extension Soils Specialist and Agronomy Extension Leader, respectively, at Kansas State University, Manhattan, KS.

PHOSPHORUS banded on acid, high-P soils enhanced wheat tillering and growth, as shown in these plots. Growth differences persisted through heading, advancing maturity.

spring growth, visual growth differences were even more dramatic. Banded P treatments, regardless of variety or lime rate, exhibited more growth, and more tillering than either the control or the broadcast P treatments (see photo above). These growth differences persisted through heading. Visual responses to banded P were much more dramatic than to lime despite the high P soil test.

First year results of this study are summarized in **Table 1**. Yields of the Al-sensitive Karl were increased 14 bu/A by banding 40 lb P_2O_5/A with the seed at planting without lime. Broadcast P was ineffective. Lime also increased Karl yields, but only 2 to 5 bu/A. Compared to previous work, the lime response was much smaller. This was likely due to very limited rainfall from the time the lime was applied (early August) through November 1. Soil samples taken in March, 1992 show the lime affected pH and KCl-extractable Al (**Table 2**), but these changes apparently didn't occur quickly enough to produce large yield increases. The Al-tolerant variety 2163 was much less affected by P and lime. This trial will be continued for a few more years.

Table 2. Effects of lime on soil pH and Al levels.

Lime	Soil pH		Soil Al, ppm	
	0-3 inches	3-6 inches	0-3 inches	3-6 inches
lb ECC/A				
0	4.9	4.9	72	71
3,750	5.7	4.9	5	66
7,500	6.2	5.0	0	70

Conclusions

Based on results of this study and Oklahoma data, it is evident that banded P applied with the seed at planting is a viable management alternative on acid, high Al soils when liming isn't possible. Both forage and grain yield can be dramatically increased. Liming is the only way, however, to effectively raise soil pH. Results clearly indicate variety selection is also important under these soil conditions. ■

Phosphorus Stress on Rice Decreases Yields

By Fred Turner and James Engbrock

New studies in Texas demonstrate the rice plant's need for phosphorus (P) and provide examples of P deficiency symptoms.

RICE is an important food crop in many parts of the world. Large acreages of rice are also grown in the southern U.S. and California. Rice is responsive to fertilization, especially nitrogen (N). But as with other crops, balanced fertility is also important.

Phosphorus Deficiency

Phosphorus deficiency on rice can significantly reduce yields. Phosphorus deficiency is often noticed on highly weathered, low pH soils. These soils may contain iron (Fe) and aluminum (Al) that bind P and make it unavailable to rice plants. Liming these soils is generally not recommended because when they are flooded, soil pH may rise one unit (i.e., from pH 5.0 up to pH 6.0).

When flooded conditions exist and pH increases, some P not normally available to upland crops (soybeans, etc.) will be released. This is due to the reduction of Fe compounds (ferric phosphates) to a more available form of P (ferrous phosphate) and to improved P diffusion to rice roots in flooded soils. At pH values above 7.0, P may be tied up as dicalcium and tricalcium phosphates, which, again, limits availability to rice.

This poses a soil testing problem because it is difficult to predict the response of flooded rice to applications of P. This Texas A&M University project is in the preliminary stages and involves soil test calibrations at a number of locations across the Upper Gulf Coast of Texas to improve soil test recommendations.

Deficiency Symptoms

With the exception of development of purple pigments in the leaves, rice P deficiency symptoms are similar to other crops:

- stunted plants
- reduced tillering
- smaller leaves
- smaller stem diameter
- poor root growth
- delayed maturity
- reduced yields

Plots reported in **Table 1** were located south of Bay City, TX on an Edna silty clay loam, pH 6.5 and very low extractable P soil test. The data show a significant increase in rice yields due to P fertilization. Even though the 120 lb/A P_2O_5 rate maximized yields in this study, higher rates of applicaion might have increased yields beyond this point.

These studies will be continued in 1993. ■

Table 1. Effect of P fertilization on rice yields near Bay City, TX.

Fertilizer treatments, lb/A N	P_2O_5	Yield lb/A
180	0	4,842
180	40	5,552
180	80	5,743
180	120	5,849

Dr. Turner is with Texas A&M University Agricultural Experiment Station at Beaumont, TX. Mr. Engbrock is with Texas A&M University Agricultural Extension Service, Matagorda County.

EFFECTS of various rates of P_2O_5 on rice growth are illustrated in this photo from June 1992, on the Mike Ottis farm. From left, the plants received P_2O_5 rates of 0, 40, 80, and 120 lb/A.

Journal of Production Agriculture Announces New Format for 1993

THE *Journal of Production Agriculture,* published by the American Society of Agronomy, will unveil a new format with the January 1993 issue. The key to the new format is the inclusion of a "Research Application Summary," which must be written in addition to the usual scientific manuscript. In order to meet this January 1993 deadline all manuscripts submitted for review *after 1 May 1992* will have to include a research application summary. The purpose of the research application summary is to facilitate communication of the information in the scientific article to the "practicing professional" in the field.

Guidelines for preparation of the research application summary are now available. The format for the scientific paper will not change, except that the interpretive summary will be omitted. The research application summary will stand alone and will be printed at the front of each issue of the journal. The scientific papers will follow in a separate section.

For more information, contact: Dr. Dwayne G. Westfall, Editor, *Journal of Production Agriculture,* Department of Agronomy, Colorado State University, Ft. Collins, CO 80523, Phone: 303/491-6149, FAX: 303/491-0564. ■

Crop Responses at High Soil Test Phosphorus Levels

By W.K. Griffith

Despite the perception that high soil test levels preclude responses to applied nutrients, a survey of recent research indicates that many other conditions influence plant response to applied phosphorus (P), even at high soil test levels. This article summarizes some of the results.

RESPONSES to applied P are usually highest on low P testing soils. However, recent research on a number of crops has shown responses to applied P on high P testing soils.

There may be several reasons why these P responses seem to be occurring with greater frequency. They include: (1) higher crop yields than were obtained in the original calibration studies, (2) increased use of minimum tillage in some form, (3) use of some equipment and management practices which tend to increase soil compaction and restrict root growth, (4) earlier planting dates when soil temperatures are cooler, (5) inadequate attention to proper soil pH levels for optimum nutrient efficiency.

An incomplete review of recent P research has identified numerous studies that produced a significant response to applied P, even when soil test levels were high or very high.

Cotton

Louisiana researchers compared applications of 6 and 10 gallons of surface-applied 11-37-0 (liquid) for cotton at planting in a 3-inch band over the row on a high-P testing soil. Lint yields were increased more than 100 lb/A by these surface-band applications. According to the researchers, the cost of the treatments would be approximately $6 and $10 per acre. Net returns increased as much as $64 per acre from the starter applications containing nitrogen (N) and P (**Table 1**).

Table 1. Yield and profits from applying P to cotton in Louisiana.

Surface band applied 11-37-0, gal/A	Lint yield, lb/A	Yield increase, lb/A lint	Net return from starter, $/A
None	949	—	—
6	1,030	81	42.60
10	1,073	124	64.40

Cotton: $0.60/lb lint High P soil test.

Field studies were conducted in four North Carolina environments to determine the effects of planting date on cotton response to side-banded starter fertilizer. Ammonium polyphosphate (APP) starter was applied at a rate of 15 lb N and 51 lb P_2O_5/A on soils testing high to very high in available P. Lint yield was increased significantly, by an average of 9 percent, across the four locations from the starter applications. Yield response to starter was consistent although overall yields declined as planting date was delayed.

Arkansas studies have shown that additional P increases yield and proportion of cotton harvested during the first pick on soils testing high in extractable P. The early first pick is important because of machine harvest and early removal of a quality product from the field. Both yields and percentage of first pick cotton were higher when P was applied to a high P-testing soil compared to medium P-testing soil (**Table 2**). Note the yield advantage of maintaining a high soil test P level, regardless of the annual P application.

Dr. Griffith, is Eastern Director, Potash & Phosphate Institute, 865 Seneca Road, Great Falls, VA 22066.

Table 2. Effects of increasing P rates on seed cotton yield and proportion of the crop harvested during first pick in Arkansas.

P_2O_5 Rate, lb/A	High P soil Yield 1st pick, lb/A	High P soil % of Crop	Medium P soil Yield 1st pick, lb/A	Medium P soil % of Crop
0	1,402	67	987	45
30	1,555	71	1,205	51
60	1,638	75	1,398	61

PHOSPHORUS response in corn shown here (at left) was on a high P testing soil. Cold, wet soils, often associated with conservation tillage systems, require supplemental P for rapid early growth, leading to higher yields.

Corn

North Carolina researchers reported the use of a starter fertilizer with a 1:1 ratio of N to P_2O_5 to be an excellent practice for high yield corn. They noted that soil P test levels are often high to very high for irrigated corn production in North Carolina, but concluded that it is important to include P in the starter for highest yields and profits.

Studies showed that P_2O_5 in the starter for irrigated corn lowered grain moisture 2.7 percent at harvest and increased yields 11 bu/A over the no P treatment when soil P test levels were high (**Table 3**). To a farmer, that decrease in grain moisture would mean as much to his profit potential (drying and/or dockage cost) as an increase in grain yield.

Table 3. Starter P_2O_5 increased irrigated corn yield and lowered grain moisture on a high P Coastal Plain soil in North Carolina.

Starter P_2O_5, lb/A	Yield, bu/A	Grain moisture, % at harvest	Gross return, $/A
0	191	20.7	380.09
58	202	18.0	429.25
Difference	11	2.7	49.16
	Difference for yield:		23.38
	Difference for moisture:		25.78

Corn price=$2.25/bu Soil test P=High
Dockage=$0.05/bu for each percent above 15.5% moisture

The importance of starter placement in corn responses to P on high P-testing soils was emphasized in several South Dakota studies. In that area, corn (dryland) tends to respond much more dramatically to P after fallow than if the land is cropped the preceding year. Loss of mycorrhizal activity during the fallow may have contributed to these responses. Starter placement has had a highly significant effect on P responses during cool growing seasons (**Table 4**). Regardless of tillage system, starter placement for corn following small grain was much more effective than broadcast, knifed, or surface stripped application.

Corn yield responses to applied P are often quite large on high P testing soils when soil temperatures are low at planting. The value of P placement close to the seed can not be over-emphasized in reduced tillage on cold soils for both row crops and small

Table 4. Influence of placement on corn responses to P in South Dakota.

Soil test level, Bray-1, ppm	Check	Broadcast	Starter	Knifed	Surface strip
			yield, bu/A		
Low (15)	110	125	139	115	122
Medium (19)	123	127	145	122	124
High (22)	124	129	145	122	127
Average	120	127	143	119	125

Rate=25 lb P_2O_5/A
Average of moldboard, chisel, and no-till systems.

grains. Wisconsin studies emphasized the value of small amounts of row-applied P for corn under such conditions (**Table 5**).

Table 5. Row applied-P significantly increased yields in this Wisconsin corn study with high P soil test.

Soil Test P, ppm Year 1	Year 2	Row P_2O_5, lb/A 0	20	40
		bu/A		
30	35	103	137	134
33	31	119	134	144
80	56	122	142	149

Withee silt loam soil.

Conservation tillage systems are an important management practice to reduce erosion and conserve moisture and are being widely advocated as an important part of the conservation management plans being implemented across the U.S.

Adequate P is a management tool which must be considered for these conservation tillage systems to ensure rapid early growth and high yields. Minnesota studies illustrate the relative importance of starter P on high P testing soils when conservation tillage systems are compared to other practices (**Table 6**).

Table 6. Response of corn to starter P fertilization on very high P testing soils in south central Minnesota.

Tillage system	Starter P applied No (Corn yield, bu/A)	Yes	Response to starter, bu/A
Moldboard	142	147	5
Chisel plow	128	139	11
Ridge plant	133	140	7
Disk	134	142	8
No-till	89	100	11

Bray P-1 = 22 ppm. Corn in rotation with soybeans.

Small Grains

Scientists at Montana State University recently completed a recalibration of the Olsen (sodium bicarbonate) P soil test for winter wheat on fallow. Rates of P_2O_5 applied with the seed ranged from 10 to 50 lb P_2O_5/A at 19 locations. Actual yields in the 3-year study varied from 12 to 77 bu/A, and P response trends were similar, regardless of the yield potential. The Olsen P soil test levels among the sites ranged from 10 to 35 ppm. These studies determined that the critical Olsen P level was 24 ppm (48 lb/A), a value much higher than the current critical levels used by many soil testing labs in the region. Phosphorus responses were smaller as P soil test increased, but responses did occur at levels which would formerly have been classified in the high range. This points out the dynamic nature of critical P soil test levels depending upon the management system in place.

PHOSPHORUS starter responses can occur on a wide range of soil test levels and are affected by a number of other soil conditions.

The importance of starter P for wheat as a management tool on acid soils high in available P has been demonstrated in recent research in Oklahoma and Kansas. Under very acid soil conditions, high aluminum (Al) availability dramatically decreases wheat forage and grain yields. However, application of starter P in direct seed contact at rates of up to 60 lb of P_2O_5/A dramatically increases both forage and grain yields and is a practical management consideration when liming is difficult and expensive (**Table 7**). Kansas studies produced similar results, empha-

Table 7. Starter P is extremely important for wheat forage and grain yields on acid, high P soils.

P_2O_5 rate, lb/A	Forage yield, lb/A 1990	1991	Grain yield, bu/A 1990
0	298	378	23
30	988	1,657	41
60	1,713	1,994	41
90	1,704	2,204	41

Mehlich III soil test P index = 155 (very high)
Soil pH = 4.5 Oklahoma

sizing the importance of P placement and variety selection on acid, high-P soils. The Oklahoma and Kansas studies do not suggest that banded P on high P soils is a permanent solution to soil acidity, but do underscore how other cultural conditions affect responses to applied P.

The importance of high soil test P values and annual fertilizer P applications for barley yields were indicated in New York studies. Fertilized barley headed earlier, withstood winter stress better and produced higher yields (**Table 8**). Note that high soil test P levels resulted in higher yields in either of the other P test categories regardless of annual P applications. Highest yields were obtained with the highest annual application rate (80 lb P_2O_5/A) and at the high soil test P level.

Table 8. Annual P fertilization and high P soil tests combine for higher barley yields.

	Soil test P level		
P_2O_5 rate, lb/A	Low	Medium	High
	---------	yields, bu/A	----------
0	7	26	70
20	14	34	89
40	15	40	95
80	21	46	100

New York

Summary

In the final analysis, soil testing is an important best management practice (BMP) to monitor soil fertility levels and to aid in crop recommendations for the future. The probability of a profitable response to P fertilization is much greater on soils that test low in available P compared to soils with high P tests. However, the possibility of a profitable response from additional P applications at high P soil tests is relatively good when other production factors are optimum or when soil, climate and management factors impose stress early in the growing season.

The increasing adoption of conservation tillage practices, accompanied by lower soil temperatures at planting, higher soil moisture content, increased possibilities of soil compaction, and accumulations of soil acidity near the surface, emphasize the need for the use of starter fertilizers containing P to enhance early seedling growth and reduce seedling stress. There is an increased need for soil test P calibration research with new tillage practices and higher yield potentials to be sure that this nutrient is not a limiting factor for yields, profits, and environmental protection through input efficiency. ■

Alabama

Calcination Effect on the Agronomic Effectiveness of Apatitic North Carolina Phosphate Rock

A GREENHOUSE study investigated the effect of calcination . . . to increase the total phosphorus (P) content of apatitic phosphate rock (PR) . . . on the solubility and agronomic effectiveness of apatitic North Carolina PR.

A silt loam soil with a pH of 4.8 was used, with four rates of P being applied. Corn was the test crop and was grown for four weeks for each of two crops.

Results showed that the degree of carbonate substitution for phosphate in the apatite was decreased after calcination, along with citrate soluble P. Both dry matter (DM) yield and P uptake were reduced. Across the range of P rates in the two crops, DM yield reduction averaged 77 percent, compared to uncalcined PR.

Researchers concluded that apatitic PR used for direct application should not be calcined, even though the process increases total P content of the mineral. ■

Source: S. H. Chien and L. L. Hammond. 1991. Soil Sci. Soc. Am. J. 55:1758-1760.

Using Phosphorus Fertilizers to Maintain Wheat Forage and Grain Yields on Acid Soils

By R.K. Boman, J.J. Sloan, R.L. Westerman, W.R. Raun, and G.V. Johnson

Oklahoma research continues to emphasize the value of seed-placed phosphorus (P) for wheat on acid soils. Data indicate that applied P lowers concentrations of aluminum (Al) in the soil solution, allowing seedling establishment. Response to applied P occurred despite high P soil tests.

WINTER WHEAT is the main cultivated crop in Oklahoma and is grown for forage and/or grain. If livestock graze the wheat and are removed by early March, both forage and grain may be harvested.

Wheat and Beef

Harvest of wheat forage by beef cattle can be a significant source of income for producers in the state and region. Low returns from grain in poor yielding years can be offset by the value of beef gains produced on the forage.

Intensive management and harvest of high yields over an extended period of time have increased surface soil acidity in many fields in north central Oklahoma. This region also extends into Kansas where soil pH values have declined to levels approaching 4.0. At soil pH levels of 4.3, some fields in this area have failed to produce a grain crop. Maintaining acceptable forage and grain yields under these conditions requires that producers make critical management decisions relative to their specific situations.

Oklahoma Conditions

Past research in Oklahoma indicated that Al toxicity to seedling wheat was a major cause of crop failure at extremely low soil pHs. Soil acidity problems in Oklahoma initially reduce wheat forage yields. If the pH drops below a critical level, grain yields can also be affected to the extent of crop failures. High concentrations of harmful Al species in soil solution result in poorly developed wheat root systems, intensifying the effects of other environmental stress factors.

In many areas, liming has been an effective and economical solution to wheat production problems resulting from soil acidity. However, because lime sources are frequently 50 to 100 miles away and lime application is very expensive, some producers do not lime fields when soil tests indicate the need. Also, under conditions of continuous monocultural wheat production, the incidence of the root disease complex (including take-all) can be increased if the soil pH is raised above pathogen threshold levels by liming. Unlike severe nutrient deficiencies that may often be recognized by symptomatic tissue color changes, yield losses on acid soils may initially occur without dramatic changes in crop appearance.

A common practice among producers who have successfully grown wheat on very acid soils has been to apply P

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OKLAHOMA studies have illustrated the importance of fertilizer P for wheat on acid soils. Despite high P soil tests, growth responses to P banded with the seed (left) have been spectacular.

fertilizers with the seed at planting. Aluminum and P react in acid soils to create a 'fixed' or unavailable form of P. This reaction is responsible for decreasing P fertilizer efficiency in acid soils. However, when P is fixed, so too is Al, since each is part of the unavailable Al-phosphate complex. This 'fixing' of Al in acid soils explains why producers who apply P fertilizer with the seed can produce normal crop yields without liming.

Research Results

Recent research in Oklahoma has focused on utilization of P as a short-term alternative to liming. Two experimental sites were selected in central Oklahoma. Sites 1 and 2 had initial surface soil pH values of 4.7 and 5.0, respectively, with exchangeable soil Al being greater in the more acid soil. However, both locations have neutral subsoils beneath the plow layer and soil pH increases rapidly with depth. In order to obtain normal production from liming, a rate of about 1.2 tons/A of effective calcium carbonate equivalent (ECCE) lime would be required. Mehlich III soil test P index values were 155 (very high) and 66 (high) at sites 1 and 2, respectively. These soil test indices were high enough that under normal soil pH conditions, no nutritional P response was expected. Phosphate fertilizer sources used included APP (10-34-0), MAP (11-52-0), and DAP (18-46-0). However, only data for APP will be presented (generally no differences among sources were recorded). Three P fertilizer rates (30, 60 and 90 lb P_2O_5/A) were banded with the seed at planting. A 60 lb/A P_2O_5 rate was broadcast preplant (data for this comparison not shown). An unfertilized check was also included.

Figure 1 illustrates the effect of several rates of APP applied with the seed at planting on wheat forage yields during the three year period 1990-1992. Forage yields were increased by a factor of 4 at site 1 and were nearly doubled at site 2. Banding of the P fertilizer with the seed was more effective for increasing forage yield than P applied broadcast preplant.

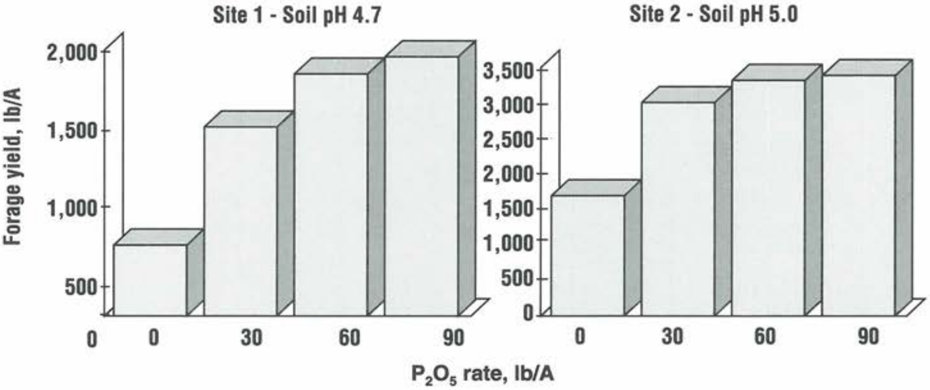

Figure 1. Applied P had dramatic effects on wheat forage yields over a 3-year period at two acid soil sites. Phosphorus as APP was banded with the seed at planting.

Grain yields at site 2 did not increase significantly from P application during the three-year period. However, on the more acid soil at site 1, grain yields were increased in 1990 and 1991 (**Figure 2**). Method of P application was not important in 1990, but the banded treatment was more effective in 1991.

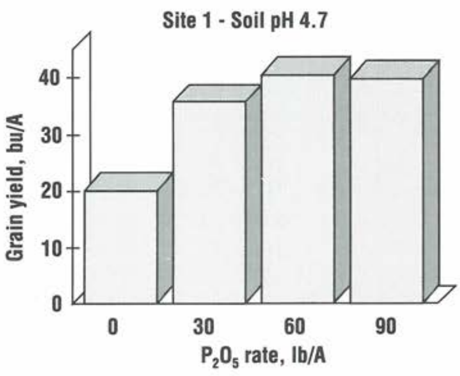

Figure 2. Banded P with the seed (APP) had significant effects on wheat grain yield when soil pH was low and P soil test was high.

Because field soil sampling techniques utilized in the first year of the experiment were inadequate to characterize the relationship of P to Al in the applied fertilizer band, a laboratory experiment was initiated. The objectives were to observe changes in soil solution composition with respect to time following the simulated banding of 0, 30, 60 and 90 lb P_2O_5/A in the strongly acid soil at site 1.

Soil solution was collected by high speed centrifugation at various times after application of fertilizer-P and analyzed for pH, Al, manganese (Mn), P and other constituents. Increased levels of fertilizer P resulted in decreased concentrations of Al, Mn and other cations in soil solution. These differences were still significant 70 days after fertilization. **Figure 3** shows relative Al concentrations over the 70-day period.

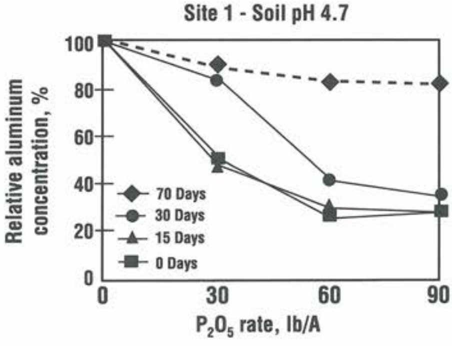

Figure 3. Relative concentration of Al in the soil solution of a P fertilizer band at 0, 15, 30, and 70 days after fertilizer application.

PHOSPHORUS banded with the seed (left) was much more effective on acid soils. The plot at right received 60 lb/A P_2O_5 broadcast compared to 30 lb/A banded (left).

FERTILIZER P sources had identical effects on wheat grain and forage yields. The area at left received ammonium polyphosphate (APP), that on the right diammonium phosphate (DAP) at the same rate of 60 lb/A P_2O_5. Monoammonium phosphate (MAP) was also included.

The GEOCHEM-PC computer model was used to assess Al speciation in the soil solution. The model showed that the sharp decrease in harmful Al was due to complexation with various P forms. The 60 lb/A P_2O_5 rate was enough to reduce the concentration of the harmful species of Al, as higher P fertilizer rates did not result in greater reductions. This finding coincided with field forage yields which were usually maximized at the 60 lb/A P_2O_5 rate. It is likely that P fertilizer is removing enough Al from soil solution near the roots to enable the developing crop to establish a better root system, thereby reducing seedling stress. Once the wheat plants become rooted below the extremely acid soil layer, the effects of Al toxicity from acidity in the surface soil are minimized.

Summary

Data from these studies show that wheat forage yields were increased by seed placement of P on acid soils with high P tests. The relative magnitude of forage yield response was greater on the more acid soil. Grain yields responded in a similar fashion, with yield responses occurring on the more acid soil, and were maximized at the 60 lb/A P_2O_5 rate.

Compared to the control, P placed with the seed was economic, even with high P soil tests. Figuring P_2O_5 at a cost of \$0.25/pound and wheat at a conservative \$2.50 per bushel, a grain yield increase of 15 bu/A from a 30 lb/A P_2O_5 application would have a value of \$42.50, more than a 5 to 1 return from P application costs. The increase in forage production from 60 lb/A P_2O_5 at a cost of \$15.00/A would produce about 140 lb/A of beef gain worth at least \$70 and approximately the same 5 to 1 return for investment in P fertilizer. Remember that a well-fertilized, well-managed wheat crop can produce BOTH beef and grain for the same investment in P fertilizer. Expense for nitrogen (N) will be higher to replace that removed in the beef, but overall net returns are improved and returns per dollar invested in P will be closer to 6 to 1 or 7 to 1.

A lime requirement of about 1.2 tons of ECCE/A for these acid soils would have represented a cost of about \$30/A and would last approximately 5 years. Maintaining maximum yields for 5 years using P placed with the seed would cost about \$37.50/A for grain production and \$75/A for forage production. Phosphorus fertilizer placed with the seed is then an effective alternative to liming strongly acid soils for winter wheat production. Use of P instead of lime is economical when lime costs are high and when considered on a short-term basis. In most instances, particularly when soil P levels are high, standard liming practices combined with provision of adequate fertilizer nutrients will be more economical for long-term management strategies. ■

Phosphorus Reduces Stress in Intensive Dryland No-Till Crop Rotations

By D.G. Westfall, G.A. Peterson, and J.L. Sanders

Adequate plant nutrition is essential for intensively managed cropping systems. Colorado studies are demonstrating the role of plant nutrients in improved yields, lower nitrate (NO_3) carryover, increased soil organic matter and weed suppression.

RESEARCH in Colorado has demonstrated that conversion from traditionally tilled, stubble-mulch, wheat-fallow systems to no-till, more intensive, rotations is economically and environmentally more sustainable in a semi-arid environment.

Even though more nitrogen (N) fertilizer is required by the more intensive, no-till cropping system, less residual soil NO_3 remains in the soil, reducing the possibility of NO_3 movement toward groundwater. The intensive, no-till system provides greater water use efficiency, higher grain yields (75 percent increase), and higher net returns (30 percent increase).

Phosphorus Reduces Stress

Maximum benefits of increased cropping intensity cannot be realized unless phosphorus (P) deficiencies are corrected. Eroded soils with low P soil tests need P fertilization along with N to allow maximum yield expression in the wheat-corn-millet-fallow rotation.

Too often, producers fail to test their soils for P and therefore lose an excellent opportunity to increase profits. Using N alone will not allow maximum return on P deficient soils.

PHOSPHORUS fertilizer increases tillering and head number of wheat on soils testing low in available P. Notice that on this P deficient soil the drill rows where 20 lb/A P_2O_5 was applied are closed by abundant tillering. Where no supplemental P was added, the rows are not closed and the soil surface is more exposed to water and wind.

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PHOSPHORUS deficiency limits early growth of many crops. In this photograph, the 20 lb/A P_2O_5 treatment advanced the early growth of dryland, no-till corn. The reduction of stress in the early stages of corn growth by P fertilization may increase yields when P is limiting.

ASSESSMENT of soil P status via soil testing is a best management practice (BMP) necessary for sustainable agriculture. Sustainable agriculture relies heavily on crop production systems that maintain or increase soil organic matter over the long term. In this study, the 20 lb/A rate of P_2O_5 increased crop residue remaining after harvest about 0.5 ton/A/year. The photograph shows a wheat-corn-millet-fallow rotation with a visual difference in surface residue due to P fertilization of a P deficient soil.

The need for good P fertilizer management is amplified as management becomes more intensive in a rotational cropping system. ■

PHOSPHORUS fertilization can also have an effect on weed suppression in crop stands. This photograph shows that where P was applied on a P deficient soil, downy brome germination and growth were dramatically suppressed. As previously indicated, P increases tillering of wheat. Increased tillering and a heavier crop canopy reduce sunlight availability for downy brome germination and growth and have an overall suppressive effect on weeds.

Alfalfa Variety Response to Phosphorus and Potassium

By Terry A. Tindall and Raymond W. Miller

Alfalfa varieties respond differently to supplemental phosphorus (P) and potassium (K), but all varieties require adequate amounts of these two nutrients to produce good yields of high quality hay.

ALFALFA HAY from the intermountain areas of Idaho and Utah is some of the most sought after in the U.S. International sales are also important. Yields have increased over the past 25 years and now approach 8 tons/A. This increase is due in part to better water management and new varieties which are better adapted to the western U.S.

Phosphorus and Potassium Critical

Nutrient requirements have increased in proportion to increased yields. Production efficiency is dependent on the availability of P and K. Once these two nutrients drop below plant critical levels, yield restrictions occur. In most western calcareous soils, the P critical level is around 12 to 15 parts per million (ppm), sodium bicarbonate extraction. The critical level for exchangeable K is about 100 to 125 ppm. If there are no other soil or management problems, growers should expect to see a response to either P or K when soil tests are below these levels.

DEFICIENCIES of P and K can lead to serious alfalfa yield losses and lower forage quality. Utah research has demonstrated these effects on a number of common varieties. The area in the center shows depressed growth due to P and K deficiency.

Deficiency Symptoms

Varieties differ in their utilization of P and K, and in their expression of K deficiency symptoms. Phosphorus deficiency symptoms are generally associated with shorter plants with a more compact leaf area. Color of normal and P-deficient plants is similar, but deficient plants may be somewhat darker green. Traditional K deficiency symptoms have been described as fawn-like spots near the leaf margins. However, other plants within the same variety and within the same area can also exhibit marginal necrosis. This is caused by high tissue sodium (Na) concentrations which result as the plant tries to come to ionic equilibrium.

Utah Studies

Experiments conducted in central Utah on a coarse-textured, calcareous soil low in K (68 ppm) and P (3.2 ppm) and with low K in the irrigation water (1.5-2.5 ppm) showed a favorable yield response to both P and K fertilizer applications. Yields were measured on three cuttings during 1989, 1990 and 1991. Fertilizer rates ranged from control levels to 458 lb/A P_2O_5 and 480 lb/A K_2O supplied as triple superphosphate (0-45-0) and potassium chloride (0-0-60). All nutrients were applied preplant and incorporated. The

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Table 1. Alfalfa yield increase with P and K with cultivars.

Variety	Treatment P_2O_5	K_2O	Year 1 Yield, tons/A	Year 1 Fertilizer Response, %	Year 2 Yield, tons/A	Year 2 Fertilizer Response, %	Year 3 Yield, tons/A	Year 3 Fertilizer Response, %	3-Year Summary Total tons/A	3-Year Summary Fertilizer Response, %
Fortress	0	0	5.5	—	6.2	—	5.0	—	16.7	—
	229	0	6.7	22.2	7.9	27.9	6.2	24.3	20.9	25.0
	229	480	7.3	31.8	8.1	31.1	6.6	31.6	21.9	31.5
DK125	0	0	5.2	—	5.7	—	3.9	—	14.9	—
	229	0	6.5	24.9	7.3	27.8	5.9	50.9	19.7	32.9
	229	480	7.1	36.3	7.9	39.1	6.3	61.7	21.4	44.1
WL316	0	0	4.7	—	6.0	—	4.7	—	15.4	—
	229	0	5.9	26.0	7.2	19.8	6.3	33.4	19.4	25.9
	229	480	6.2	31.5	7.7	28.2	6.3	33.2	20.2	30.7
P-5432	0	0	5.5	—	6.8	—	5.7	—	18.0	—
	229	0	6.7	20.9	7.7	13.8	6.8	18.2	21.1	17.4
	229	480	7.3	31.2	8.1	19.4	7.0	23.2	22.4	24.2
Vector	0	0	4.5	—	5.9	—	4.0	—	14.1	—
	229	0	6.3	38.6	7.7	37.7	6.1	51.2	20.0	41.8
	229	480	6.8	49.8	8.1	44.1	6.2	53.4	21.0	48.6

study involved five alfalfa varieties especially selected for regional environmental conditions. Yield data for three cuttings/year for three years are presented in **Table 1**.

Results

Production levels were increased by fertilization in all three years of the study, regardless of variety. The greatest percent increase over the control occurred when only P or P-K combinations were applied. Yield increases from P and K varied from year to year, but were significant each year. There was a positive response to K alone, but the yields were not nearly as high as when P was supplied. Apparently, alfalfa grown under the conditions of low P and low K needs to satisfy the P requirements prior to that for K. However, P and K in combination increased dry matter yields up to 11.2 percent over P alone for the three-year period.

Varietal Effects

The individual varieties did not respond similarly to P or K applications. Yields in the third year were increased 23.2 to 61.7 percent by P-K applications, depending on variety.

There was a much greater difference among variety yields that were not fertilized than when adequate P and K were provided. This would indicate that the selection for release of these varieties was based on soils which were not deficient in either P or K. Selection of a variety would be more critical for soils where P or K is expected to be limited. But when adequate P and K are provided, this study indicates little difference in variety performance.

Phosphorus and K applications affected tissue concentrations of P, K, and Na (**Table 2**). Whole plant samples were

(continued on page 25)

Table 2. Concentration of P, K, and Na in alfalfa tissue of the 1st and 3rd cutting, 1990.

Treatment P_2O_5	K_2O	% P Cutting 1st	% P Cutting 3rd	% K Cutting 1st	% K Cutting 3rd	% Na Cutting 1st	% Na Cutting 3rd
0	0	0.16	0.20	1.25	1.32	0.14	0.23
0	240	0.15	0.18	1.36	1.57	0.12	0.17
0	480	0.14	0.17	1.47	1.53	0.08	0.14
229	0	0.20	0.23	1.12	1.27	0.22	0.31
229	240	0.19	0.24	1.42	1.44	0.15	0.24
229	480	0.18	0.22	1.25	1.48	0.12	0.18
LSD 0.5		0.02	0.03	0.19	0.25	0.04	0.08

Phosphorus Management Can Reduce the Effects of Soil Salinity

By Paul E. Fixen

Soil salinity is a limiting factor for crop production for many growers in semiarid regions. Both old and new research highlight the importance of phosphorus (P) management on these salt-affected soils.

SOIL SALINITY reduces the yield potential of vast acreages in western North America. The USDA Salinity Laboratory has estimated that nearly 8 million acres are classified as salt affected in the 17 western states of the U.S., including Hawaii. In many cases, water is not available to leach the salts below the root zone and growers must modify crop selection and management to minimize the negative effects on yields and profitability.

Early Research

Phosphorus can play a critical role in the successful management of these soils. As early as 1950, researchers observed that cereal crops growing in moderately saline soils in the glaciated eastern Dakotas often exhibited P deficiency symptoms. These observations caused them to conduct greenhouse and field experiments that generated similar and striking results. The field trial was conducted on a silt loam soil.

Dramatic oat and barley responses to P resulted, especially when banded with the seed (**Figure 1**). Researchers Fine and Carson wrote, "The symptoms usually noted and tentatively regarded as typical salt injury were completely alleviated in all plots receiving P in amounts over 40 lb P_2O_5/A broadcast, or 20 lb P_2O_5/A applied with the seed. The crop appearance was entirely normal in the case of both oats and barley in the phosphated plots, but the others and the oats in the field surrounding the experiment again showed the typical necrotic leaf tip in the seedling stage and later, copper-colored lower leaves and stunted growth, with a dark bluish-green color appearing in the upper leaves as the season progressed."

Later Research

Since this early study, several other researchers have demonstrated that P and salts interact. Nebraska researchers found that increasing salinity decreased both P uptake and P concentration in barley and corn plants. Increasing salinity in a California study reduced P concentration slightly in rye, a very salt-tolerant crop.

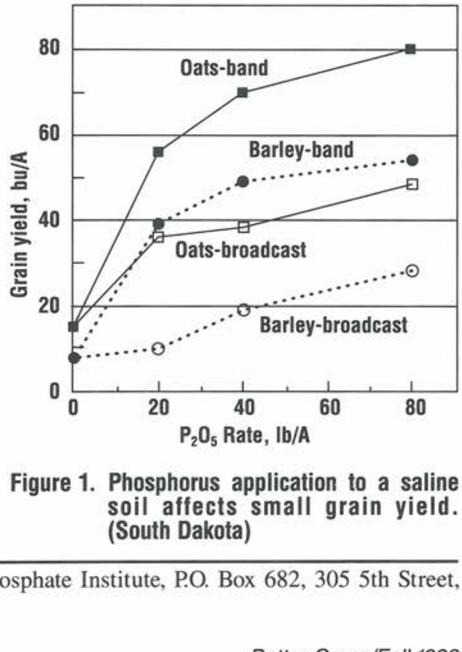

Figure 1. Phosphorus application to a saline soil affects small grain yield. (South Dakota)

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Phosphorus-enhanced salt tolerance in tomato has been demonstrated in Australia with higher than normal P levels required when tomatoes are grown in saline environments. Similar results have been reported for the salt sensitive crops, millet and clover.

PLANTS on salt-affected soils frequently show symptoms similar to those of P deficiency.

Progress has been made in our understanding of how P increases salt tolerance of crops. The observation that plant P uptake and concentrations are often reduced as salinity increases suggests that higher soil or fertilizer P levels may be needed to compensate. Plants with adequate P appear to have an enhanced ability to regulate ionic distribution among leaves of different age, causing reduced levels of sodium (Na) and chloride (Cl) in sensitive young tissues.

Summary

Growers with salt-affected soils should be aware of the importance of providing adequate P to their crops. Banding has been the most effective method of application. The potential exists for a need to adjust soil test P interpretation for saline soils. However, the magnitude of the adjustment, if any, has not been defined. Monitoring the P status of crops using plant analysis may help determine if current practices are sufficient. ■

Alfalfa . . . from page 23

collected during the 1st and 3rd cutting of the second year. Phosphorus tissue concentrations ranged from 0.14 to 0.24 percent and related nicely to treatment effects. Phosphorus levels decreased with initial K application when plant P requirements were not being satisfied. When adequate levels of P and K were present in the soil system, P tissue level was 0.18 to 0.20 percent for the first cutting and 0.22 to 0.24 percent for the third cutting. These concentrations reflect critical P levels for whole plants and for the alfalfa varieties evaluated.

Tissue K levels ranged from 1.12 to 1.57 percent when only P or K was provided. When both P and K were at adequate levels, tissue concentrations for the first cutting ranged between 1.25 and 1.42 percent. Third cutting of alfalfa contained higher overall concentrations of both P and K.

Sodium uptake is noteworthy as it relates to K. There is a direct competition within the plant between K and Na. When soil K is high, Na in the tissue is low. The opposite occurs when soil K levels are deficient or low. An increase in tissue Na results in the marginal necrosis seen on some cultivars. This necrosis should be identified as a K deficiency symptom, although it is not always recognized as such.

Summary

In the final analysis, adequate supplies of P and K must be made available to all alfalfa varieties for top yields and top profits. Adequate plant nutrition is essential for efficient production, high water use efficiency, and production of a high quality crop. Although alfalfa varieties do differ in their abilities to cope with low P and K availability, adequate P and K fertilization is essential for all varieties in a profitable production operation. ■

Great Plains

Phosphorus: Impact on Small Grain Plant Development

By Carl Fanning and Jay Goos

Phosphorus (P) has dramatic impact on small grain plant component development, including tillers, roots, heads and, in some varieties, leaves. Yield loss with stressed plants occurs when components are sacrificed or simply fail to develop. Today's management requires early season damage assessment. Critical plant components are easy to count and evaluate.

PHOSPHORUS fertilization of small grains in low rainfall areas has been a key to profitable management for several decades. In the Great Plains and Prairies, years of dedicated research have provided a well calibrated soil testing program which most growers understand and use regularly. However, few growers recognize or understand how P changes small grain growth to increase yield. Nitrogen (N) is also needed. The lush green, rapid rate of growth provided by N dominates grower impressions of what's essential for a high-yielding crop.

Rainfall limits yields and increases production risk across this region. Production research has alternately examined factors to increase yields or control costs. Recent work focused on banding P with N as a technique to reduce cost. This is achieved partially through more efficient P use, but more specifically through combined operations that reduce trips through a field. It's been an effective program. The proliferation of new grain drill and fertilizer equipment designs for band placement reflects the program's success. However, in addition to reduced costs, band placement has

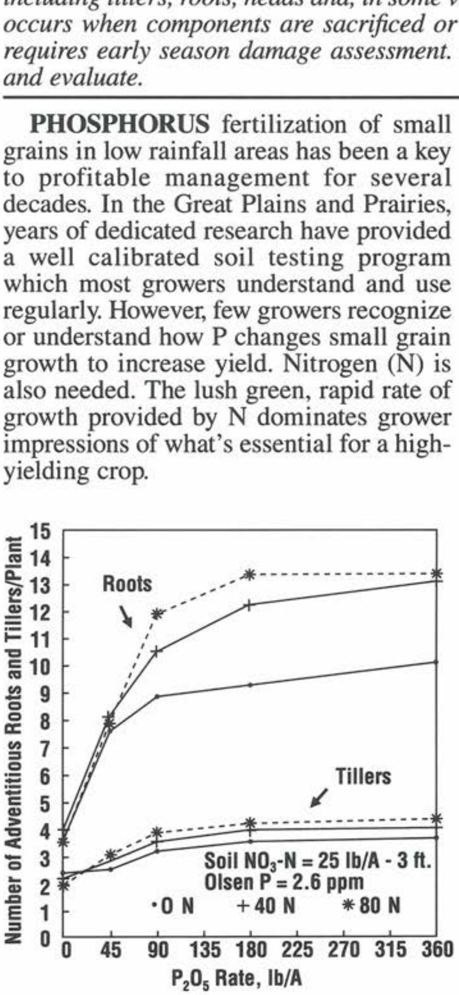

Figure 1. Spring wheat adventitious roots and tillers as influenced by phosphorus and nitrogen fertilization. (USDA-ARS, Montana)

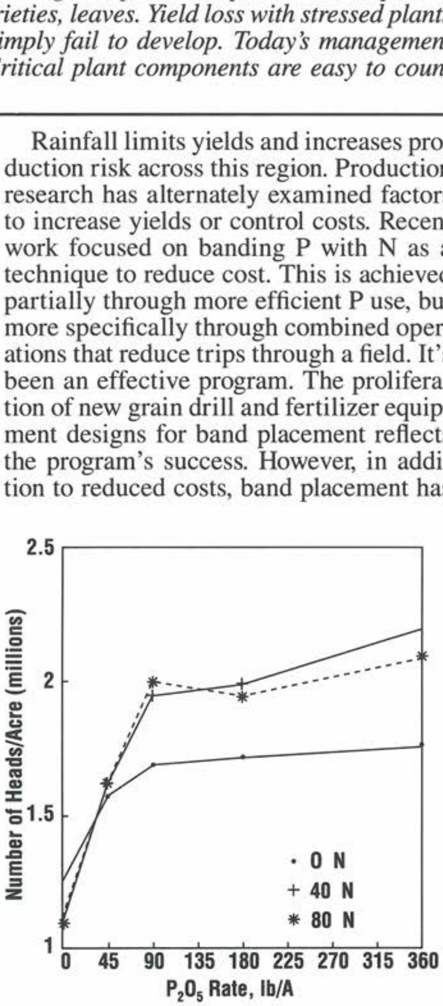

Figure 2. Spring wheat heads per acre as influenced by phosphorus and nitrogen fertilization. (USDA-ARS, Montana)

Dr. Fanning is Extension Soil Specialist, North Dakota State University Extension Service, Fargo. Dr. Goos is Professor of Soil Science, Dept. of Soil Science, North Dakota State University, Fargo.

has also provided growers a yield increase. The yield increase is technically and economically interesting . . . good reason to re-examine how P effects small grain development and yield.

Risk Control

Risk levels in low-rainfall-area small grain production are such that any easily identified plant growth factor becomes a valuable management tool.

It's significant that early research identified increased water use efficiency with P fertilization. Some envisioned P fertilization as a tool to moderate drought risk. However, identification of crop response mechanisms attributable to P languished and was overshadowed by recognition that both yields and water use efficiency maximized with combined N-P applications. Without plausible, easily described mechanisms, growers have not been interested in P fertilization to control low-rainfall-year risk.

Research Contributions

Spring wheat research at Sidney, Montana, provided key data. A number of plant measurements were made, including a count of adventitious roots (**Figure 1**). Adventitious roots in a small grain crop are those that grow from the crown as a complement of new roots for each new tiller added. Researchers observed that four adventitious roots were normally required to mature each head and that root counts were a more reliable early season indicator of potential head numbers than tiller counts.

Adventitious roots dominate the root mass of a mature wheat plant. Rationally, a large adventitious root system can provide a plant more extensive soil mass exploration and increase potential for efficient use of water or nutrients the soil contains.

Spring wheat yield in the Montana study peaked with the 40 lb/A N application rate. Simple comparison of root numbers (**Figure 1**) with 0 and 40 lb N/A rate show P is responsible for about 75 percent of adventitious root development. Clearly, the role of P in root development overshadows N. Similarly, head count numbers attributable to P are quite high and dominate plant response (**Figure 2**).

Reduced tillering is often listed as a characteristic of P-deficient small grains. Failure to develop tillers 1 and 2 as shown in **Figure 3** can be especially damaging in spring grain. These tillers mature with the mainstem head and have higher yield potential than later tillers. It's common to find this problem across eroded landscapes and in fields subjected to severe

(continued on page 29)

Table 1. Spring wheat main stem leaf number as influenced by phosphorus fertilization.

	P, mg/pot	
Variety	0	50
	% of plants with 8 main stem leaves[1]	
Amidon	100	100
Butte 86	28	96
Grandin	0	92
Len	87	100
Marshall	100	100
Stoa	71	100

[1]Other plants had 7 main stem leaves.
North Dakota research: Goos, Johnson, Feuchtenbeiner

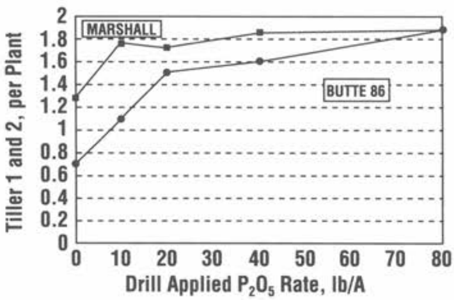

Figure 3. Reduced tillering is a characteristic of phosphorus-deficient small grains.

Saskatchewan Research

Yield Response of Spring Wheat to Seed-Placed Phosphorus

By R.P. Zentner, C.A. Campbell, and F. Selles

A 24-year Saskatchewan study has shown spring wheat continues to respond postively to seed-placed phosphorus (P) in spite of marked increases in available soil P due to fertilization. Yield increases were related to spring and summer climatic conditions.

WHEAT YIELD RESPONSE to seed-placed P has been observed for many years in the Canadian Prairies. This pop-up effect is particularly notable when soils are cool and wet in early spring. With soil P levels rising from the more frequent use of P fertilizers over the past 40 to 50 years, there is some question as to whether crop response to starter P has been decreasing due to this buildup of soil available P.

For 24 years, we have monitored yield and bicarbonate-extractable soil P (Olsen-P) annually on twelve cropping systems on a medium textured, Orthic Brown Chernozem at Swift Current, Saskatchewan. These data provide an opportunity to reassess crop response to starter P under conditions of soil P buildup. Two of the 12 crop rotations were examined in this study. Both systems were fallow-wheat-wheat (F-W-W), one receiving nitrogen (N) plus P and one receiving only N.

Results

The initial level of soil test P (Olsen P) at the start of the study (1967) was 17 lb/A and, after 24 years of cropping without P fertilizer application, the P test level did not change (**Figure 1**). The P removed in the grain, the only major source of P export from the system, averaged about 7 lb P_2O_5 /A/yr. This amount is about equal to that being generated through P mineralization from soil organic matter and physiochemical transformation of less available forms of inorganic P, because the unfertilized system has not decreased over the 24-year period.

Addition of P fertilizer, at an average annual rate of 13 lb P_2O_5 /A/yr, increased soil test P by about 0.8 lb/A each year of the study. The P exported in the grain in the fertilized rotation averaged about 8 lb P_2O_5 /A/yr of P. Therefore, P_2O_5 input was 5 lb/A/yr greater than export, suggesting that about 36 to 38 percent of the extra fertilizer P had entered the Olsen P fraction of the soil.

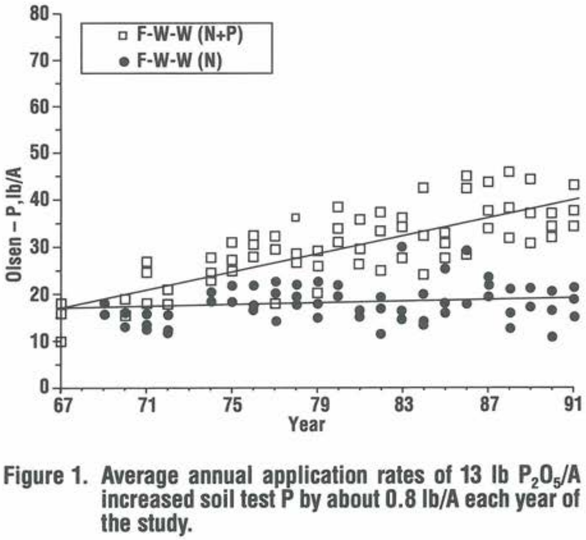

Figure 1. Average annual application rates of 13 lb P_2O_5/A increased soil test P by about 0.8 lb/A each year of the study.

The authors are research scientists with Agriculture Canada, located at Swift Current Research Station, Saskatchewan, Canada.

Phosphorus application produced an average of 2.8 bu/A more grain for wheat grown on fallow, and 2.0 bu/A more grain for wheat grown on stubble (**Figure 2**). These increases were consistent over the 24-year period and occurred as frequently in the latter half of the study as the first half. Thus, the gradual build-up in available soil P due to fertilization did not appear to dampen the response to P fertilizer. This shows that, although frequent use of fertilizers will increase available P levels in prairie soils, farmers may still experience significant yield response to small applications of P fertilizer placed with the seed.

The variability in yield response was closely related to the influence of spring weather conditions. For example, for wheat grown on fallow, yield reponse to P was directly related to temperature between emergence and 3-leaf stage but was depressed when soils were very wet at seeding. The positive relationship between yield and temperature may be because bare fallow soils are often moist and therefore cool in early spring. Because they have been fallowed, they are likely to have sufficient available P but, at low temperature, plant root growth will be slowed, as will available P uptake and translocation within the plant.

The literature suggests that fertilizer P placed close to the seed will be extremely important because early spring is the period when wheat makes maximum use of fertilizer P. In contrast, the importance of soil P increases rapidly from about four weeks after emergence. The negative relationship between yield response to P and precipitation at seeding may be the result of excessive water due to the combination of high levels of stored water plus high early May precipitation. For wheat grown on stubble, response to P was greater when soil temperatures were low at about 3- to 4-leaf stage. This type of response is similar to that obtained in growth chamber studies by other scientists.

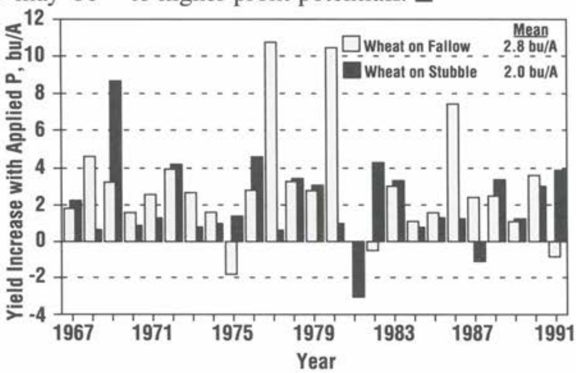

Figure 2. Phosphorus application produced an average of 2.8 bu/A more grain for wheat grown on fallow and 2.0 bu/A more grain for wheat grown on stubble.

Summary

Although prairie soils may have higher levels of soil available P resulting from decades of P fertilizer use, seed-placed P can still offset some yield variability related to climatic conditions and can result in moderate to substantial yield increases. Under excellent growing conditions, seed-placed P can aid plants in reaching higher yield capabilities leading to higher profit potentials. ■

Plant Development . . . from page 27

early season drought. Leaf development failure may also serve as a P deficiency symptom, based on results from a greenhouse study evaluating several hard red spring wheat varieties (**Table 1**).

Summary

Most spring wheat varieties will develop eight leaves on the plant main stem. Data indicate that varieties differ in P response for both tiller and leaf development. The significance of this lies with the fact that leaf development loss hasn't been recognized as a small grain production management concern. Like tiller and head count numbers, small grain adventitious roots and mainstem leaves are easy to count and evaluate and are related to crop yield potential.■

Environotes from TVA

By John E. Culp

FERTILIZER and agrichemical dealers across the country are adopting improved practices to help prevent accidental releases of waste streams into surface and groundwaters. Secondary containment structures are being built as one way to prevent such problems.

TVA is working with dealers in two major demonstration programs: model site and individual technology demonstrations. We will periodically highlight lessons learned at these demonstrations in this column. Emphasis is on containment structures and environmental practices.

The individual technology demonstration at the Service and Supply Cooperative in Bellflower, MO, was highlighted during a recent open house. This demonstration is a completely new MAP suspension facility designed by TVA engineers. It is an excellent demonstration for dealers with MAP suspension programs. The latest in environmental techniques is being demonstrated at Bellflower. Visits to the site provide a great deal of information about techniques used to prevent environmental problems.

After containment, what is next? Many believe remediation will be–and perhaps already is–the major concern. There are technologies available for solving contaminated site and waste stream problems–including land disposal. Most current technologies are extremely expensive.

TVA is directing a great deal of research toward developing cost-effective remediation technologies to clean up sites and treat waste streams. They range from bioremediation to simple separation or more sophisticated physical/chemical technologies. Let's highlight TVA's approach in three areas.

Bioremediation: This could be an ideal route to destroy pesticide residues in soils.

CONSTRUCTED WETLANDS facility at TVA.

TVA is in the early stages of research to evaluate various microorganisms to break down pesticides and determine the optimum conditions needed to enhance bioremediation. TVA will investigate bioremediation in laboratories, in greenhouses, and at plant sites.

Solar Evaporation: TVA is investigating solar evaporation to concentrate pesticide-containing water. We have established testing and demonstration units in Washington and Idaho and at Utah State University to collect data and demonstrate the technology.

Constructed Wetlands: TVA is conducting research in its newly constructed wetlands facility to determine the potential for this technology in cleaning up nutrient and pesticide waste streams. The idea is to determine the capability of aquatic plants in a wetlands setting in cleaning up wastes from agricultural operations.

Lessons Shared

TVA joined public and private organizations recently in Kentucky to conduct a pesticide collection workshop. Potential problems and proposed solutions were discussed for publicizing and conducting

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pesticide collection (amnesty) days for farmers to bring their unused or outdated pesticides to a central point for handling and disposal.

Cooperators included EPA's Region IV officials, The Commonwealth of Kentucky Natural Resources and Environmental Protection Cabinet, and Agriculture Coalition for the Environment.

The workshop keyed on lessons learned at the Kentucky pesticide collection day. Topics covered included a review of regulations relating to pesticides; precollection events such as planning, liability, and publicity; and collection day events such as receiving, handling, safety, storage, and transportation. Officials from several states attended and were interested in developing similar programs.

Billy Joe Miles, a fertilizer industryman from Owensboro, KY, told the group that common sense is needed to get programs like this conducted. "We've just scratched the surface in getting farmers to bring in their chemicals," he said. Miles recommended that the next step is to develop exchange programs so that usable chemicals can be provided to other farmers. This would eliminate the need for incineration and provide chemicals others can use. Proceedings of the workshop are being published.

Pollution Prevention

TVA organized a session in Washington to explore the EPA/USDA agreement to enhance those agencies' pollution prevention efforts in the agricultural sector. TFI's staff and several fertilizer dealers participated in the September session.

The agricultural pollution prevention initiative specifically targets voluntary actions of growers, producers, processors, and suppliers of the agricultural sector. Dr. Harry Wells, EPA, and Dr. Barbara Osgood, USDA, provided an overview of their pollution prevention initiatives. A key focus of the session was for fertilizer dealers and other industry people to discuss the voluntary efforts they have under way to prevent pollution. TVA staff also discussed how research has been targeted to environmental protection and the work TVA does with the industry in pollution prevention.

Meetings such as this offer the opportunity to inform USDA and EPA of TVA's and industry's interest in environmental protection.

Educational/Training Presentation

TVA staff are intensively involved in developing and introducing improved management practices for use by fertilizer and ag chemical dealers. Emphasis is on environmental practices. Several video presentations are being produced and will soon be available.

- "Calibration of Anhydrous Applicators" (now available)
- "Environmentally Safe Handling of Fertilizers and Agrichemicals at the Grower Level" (will be available in English and Spanish)
- "Safe Transportation of Anhydrous Ammonia by Truck"

Proceedings from the February 1992 conference on "Designing Facilities for Pesticide and Fertilizer Containment" is now available–from TVA and Midwest Plan Service. TVA was a co-sponsor of the conference.

TVA Conference

The "Environmental Realities in the '90s" conference was held in August in St. Louis. Sessions were conducted on clean water and transportation legislation/regulation, FIFRA 88, and SARA Title III. Other sessions explored developing and operating an environmentally sound dealership. This included educational tools to help the dealer, financing issues, and building secondary containment systems.

Co-sponsors of the conference include The Fertilizer Institute, Agricultural Retailers Association, Potash & Phosphate Institute, National Agricultural Chemicals Association, and National AgriChemical Retailers Association. Proceedings of the meeting are available from TVA. ■

Truth or Fiction

"Ye shall know the truth and the truth shall set you free." *John 8:32*

But what IS the truth? In environmental issues we should present the whole truth and nothing but the truth. Almost no one deliberately tries to deceive the public, but often information is only **partial** truth–not established by carefully conducted research.

Our goal is a productive and sustainable agriculture–one that protects the environment and provides a safe and adequate food supply. Over the years, our colleges and official research agencies have developed the information that makes this possible. **They strive to give the world the whole truth**.

But it seems that some interest groups and some news media, in their zeal to spread the alarm about "life-threatening" chemicals–or about the wonders of "natural" products–succumb to partial truths that lead to unfounded beliefs.

A nationwide survey indicated that (a) most Americans believe pesticides are a more serious concern than cholesterol; (b) well over half of the public say they prefer organic fruits and vegetables; (c) 44 percent would pay a higher price to get them. What's behind such beliefs? The old story: "The fewer the facts, the stronger the opinions."

So scientists are faced with an added responsibility: to give both the public and the media all FACTS developed through years of painstaking research. If they don't, the current and widespread dissemination of partial truths could jeopardize the future world food supply.

J. Fielding Reed

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