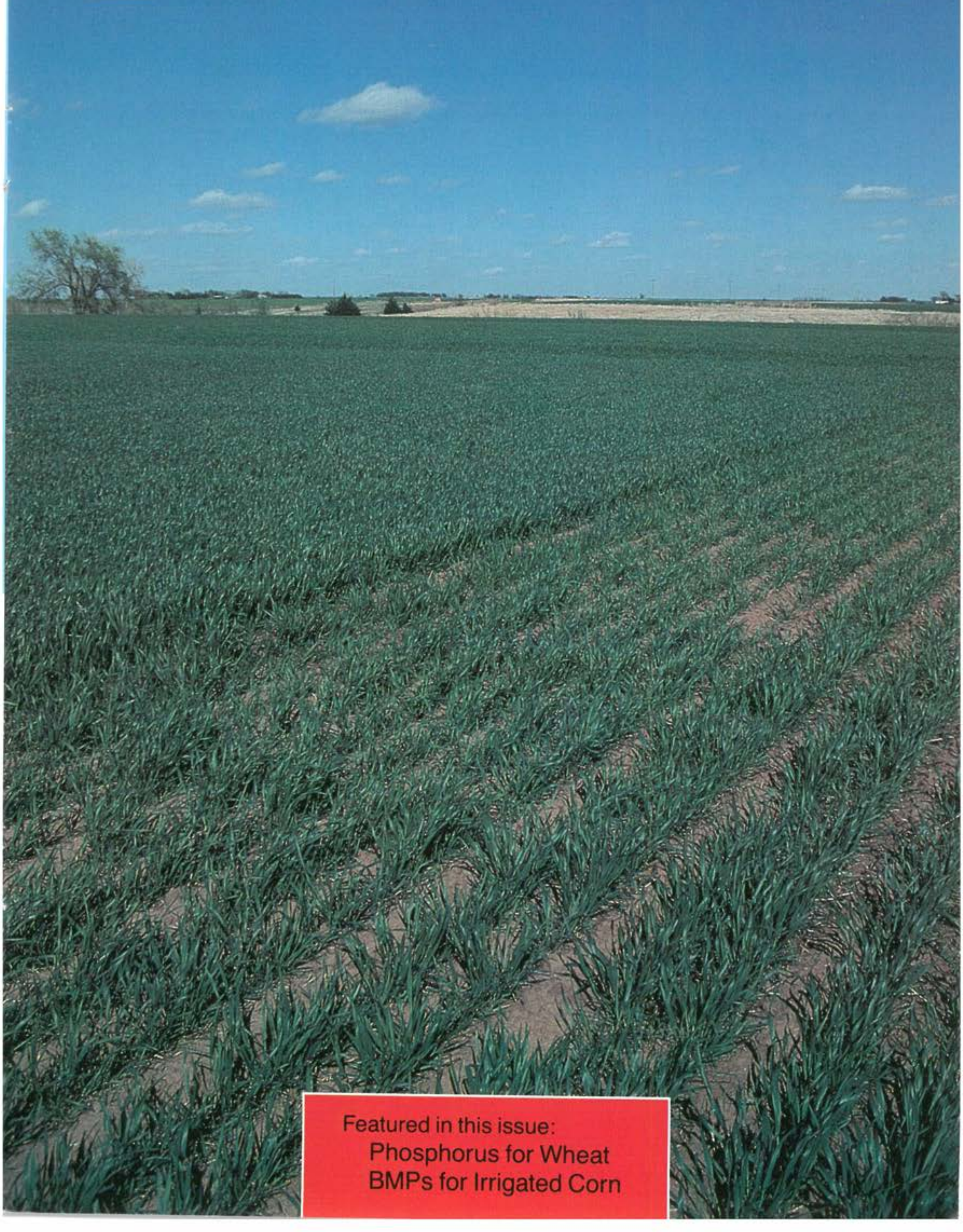
BETTER CROPS

WITH PLANT FOOD

Summer 1991



Featured in this issue:
Phosphorus for Wheat
BMPs for Irrigated Corn

BETTER CROPS With Plant Food

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Contents

Our Cover: Wheat with 60 lb/A of P_2O_5 band-applied showed dramatic response compared to plots with no P_2O_5 applied. Oklahoma State University research at Carrier, OK.
Photo by Dr. Larry S. Murphy.

Irrigated Corn: Developing a Profitable Production System with Best Management Practices

By John R. Anderson

Profitable corn production can be grown on nutrient sensitive watersheds with minimum impact on the environment when a system of best management practices (BMPs) is used. The system, developed over a period of years through an extensive research and on-farm demonstration program, is the result of integrating the various inputs at optimum levels to obtain a high degree of efficiency. BMP research is the foundation for a profitable crop production system.

IRRIGATION CAPABILITIES in the southeastern United States have steadily increased since the early 1970s. Irrigation more than doubled in North Carolina, now exceeding 400,000 acres. As in other southeastern states, a large percentage of North Carolina's irrigated acreage is dedicated to corn production. Southeastern corn growers have clearly demonstrated that profitable, high corn yields can be attained when specific inputs and cultural practices are combined with proper irrigation scheduling.

Irrigated corn production technology employed by North Carolina growers has evolved over the past decade and involves a "package" of BMPs designed to produce corn profits without off-site movement of nitrogen (N), phosphorus (P) or pesticides. These BMPs are the product of an extensive series of on-farm experiments and demonstrations supported, for the most part, by the Foundation for Agronomic Research (FAR).

Much of the irrigated corn production system was derived from research conducted in a seven-year experiment on a typical, coastal plain, loamy sand near Wilson, NC. As the study progressed, positive changes in the system were made. Corn grain yields rose from 166 bu/A in year one to 219 bu/A in year three (**Table 1**). As experience was gained at Wilson and other sites, yields increased to an average of 245 bu/A over the last four years. Non-irrigated yield average for the seven year period was 131 bu/A compared to the Wilson county non-irrigated yield average of 75 bu/A during the same period.

As development of the irrigated corn production system proceeded, it was evaluated on a larger scale in commercial fields in 1985 and 1986. Grain yields in Bertie and Edgecombe counties were in the 215 to 220 bu/A range, 45 to 70 bu/A above yields in adjoining farm fields. Following the large-scale testing, the system was presented to North Carolina irrigators as a management "package." The BMPs forming that package have been modified only slightly since.

Best Management Practices

Tillage. Match tillage systems to soil types. Deep-till sandy, light or dark-colored, coastal plain soils. In-row

Table 1. Progress in development of a BMP irrigated corn production system for North Carolina.

	Corn Yields, bu/A	
Year	Irrigated	Non-Irrigated
1980	166	88
1981	194	90
1982	219	196
1983	237	188
1984	262	204
1985	250	13
1986	222	137

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A "PACKAGE" of best management practices has helped growers of irrigated corn in North Carolina to generate profits and high yields with minimum environmental impact.

subsoiling on those soil types increases nutrient uptake and water usage from beneath hardpans. Often, chisel plows do not fracture hardpans in sandy soils and they are more effective in soils containing more silt and clay. On clayey piedmont soils, retaining prior crop residues on or near the soil surface increases water infiltration, irrigation water use efficiency and corn yields.

Hybrid Selection. Select medium-maturing, disease resistant, corn hybrids that will tolerate high plant populations. With ample water, medium season hybrids yield as well as full-season hybrids and may be harvested at lower grain moisture, usually commanding a higher selling price. Hybrids should tolerate plant populations of 29,000 plants/A because that density, in 30-inch rows, produces optimum yields with center pivot irrigation. Growers utilizing hose-reel or cable-tow irrigation systems should establish a final stand of 24,000 to 26,000 plants/A because they may have difficulty meeting corn water requirements during extended dry periods.

Potash (K_2O). Apply 100 to 150 lb/A potash. Do not exceed a nitrogen (N) to potash ($N:K_2O$) ratio of 2:1. The high humidity and plant populations associated with irrigation encourage stalk rot diseases. The incidence of stalk rot and associated lodging is increased further by high $N:K_2O$ ratios. Lodging common to irrigated corn is best reduced by adequate potash fertilization and careful hybrid selection.

Starter Fertilizers. Use a starter fertilizer with a 1:1 ratio of N to phosphate (P_2O_5). Fluid or solid fertilizers work equally well when 2 × 2 placement is used. Although soils used for irrigated corn production often test high for soil phosphorus (P), it is important to include P in the starter fertilizer. North Carolina research has shown that starter P in the irrigated corn package lowers grain moisture at harvest and may increase yield even at high soil test P levels. Phosphorus in the starter reduced grain moisture at harvest 2.7 percent and increased yield by 11 bu/A

(continued on next page)

(**Table 2**). On sandy coastal plain soils, include sulphur (S) in the starter fertilizer at a rate of 5 to 10 lb/A. In some starter materials, manganese (Mn) or zinc (Zn) may be included if soil test levels indicate those micronutrients are needed.

Table 2. Starter P_2O_5 study on irrigated corn (North Carolina)

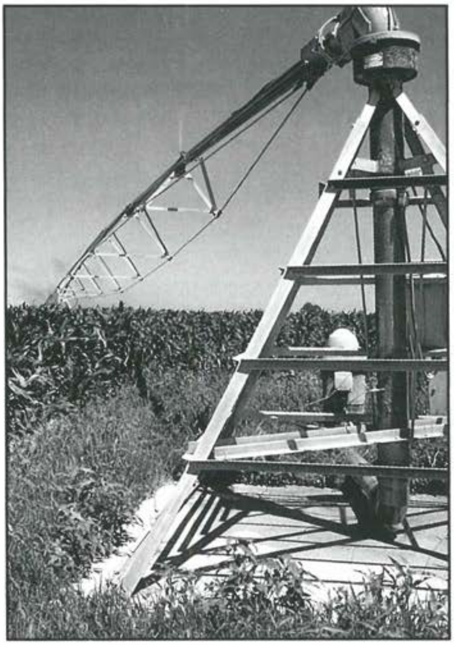
Starter	Yield, bu/A	Grain Moisture at Harvest, %	Gross Return; $/A
P_2O_5 included	202	18.0	429.25
No P_2O_5	191	20.7	380.09
Difference	11	2.7	49.16
		Difference for yield:	23.38
		Difference for moisture:	25.78

Corn price = 2.25/bu.
Dockage = $0.05/bu for each percent above 15.5 percent moisture.

Nitrogen Management. Apply 200 lb/A of N in multiple applications. With ground equipment, a proven approach is 40, 120 and 40 lb/A N at planting, side-dress and pre-tassel stages, respectively. More frequent applications are possible where fertigation equipment is available. Additional S may be added with N applications to maintain a N:S ratio of 12:1 or less. In rotations that produce significant quantities of residual N (such as peanuts followed by corn) there may be opportunities for further refinement of N recommendations. Studies are underway to determine the usefulness of soil nitrate tests for determining appropriate N rates for irrigated corn.

Pest Management. Apply soil insecticides and broadcast or band herbicides according to field histories. Since irrigated corn grows quickly, particularly when starter fertilizers are used, banded herbicides plus a cultivation often provide acceptable weed control. An exception is where highly competitive weeds like broadleaf signalgrass and Texas panicum are present.

Field histories are especially important to irrigated corn growers. They facilitate the selection of soil insecticides as well as weed management options. For example,



irrigation is most often used to enhance production on sandy, mineral soils. When well-drained, mineral soils with no history of soil insect problems are rotated annually, the probability of an economical response to a soil insecticide is very low. If corn is grown continuously on those fields or soil insects have been a problem, then a soil insecticide that controls the anticipated insect(s) should be used.

Irrigation Scheduling. High-yielding corn requires large quantities of water. Irrigation scheduling research has shown that the interval between V12 and black layer formation is critical for irrigators. Southeastern growers tend to begin watering too late in the growing season and generally wait too long after rainfall events to resume irrigations.

An overlooked water management practice is cultivation. A single cultivation increases water infiltration while improving weed control. When conservation tillage is used, crop residues can substitute for cultivation and enhance irrigation water use efficiency. ■

California Research

Cotton Yield and Fiber Quality Improved with Potash

By Bruce A. Roberts

Potassium (K) deficiency of cotton grown in the San Joaquin Valley of California is not new. Reports of the problem began in the mid-1950s. Only in recent years, however, has the problem been generally recognized. The introduction of high volume instrumentation (HVI) classification of cotton offers growers an added benefit from K fertilization–a premium for higher quality in addition to more yield.

POTASSIUM fertilization of cotton is perhaps today's most widely discussed production topic across the Cotton Belt. Results of recent research by university, Extension and other government personnel have been impressive. Substantial yield responses to K, affecting large acreages, are being documented in most cotton states.

Recent issues of this publication have reported on K research evaluating deficiency identification (Maples, R.L., et al., Winter issue 1988-89), deep placement technology (Tupper, G., Winter issue 1987-88), and supplemental foliar applications (Oosterhuis, D.M., et al., Summer issue 1990).

The probability of increased yields is sufficient incentive for growers to pay close attention to available soil K and seasonal tissue K levels. An additional incentive is the value added to cotton lint from improved fiber quality. This aspect of fiber quality as related to K nutrition has become even more important with the adoption of HVI.

HVI Sets the Standard

The new HVI classification of cotton is an automated system replacing the traditional manual classification system. Measurements are made for fiber length, strength, length uniformity, micronaire, trash content, and color. Adoption of the HVI system in the U.S. signals a move toward a determination of price based on fiber quality measured on each bale entering the market. The HVI evaluation is the accepted standard for merchants and spinners throughout the world and will become the official system of classification for the U.S. with the 1991 crop. On-farm management that affects fiber quality, therefore, takes on much greater importance as to marketability and value of the crop than ever before.

The California Experience

A three-year field trial was conducted in Kings County, California, to determine the effect of K fertilization on lint yield and quality of cotton grown on an irrigated vermiculitic soil. This study was under the direction of Dr. Kenneth G. Cassman, formerly in the Dept. of Agronomy & Range Science, University of California-Davis. A single variety (Acala SJ-2) was grown in 1985 and two varieties (Acala SJ-2 and GC-510) were grown in 1986 and 1987. Potassium was broadcast and incorporated each year prior to planting at 0, 125, 250, and 500 lb/A of K_2O on 10 blocked replications. The K applications were repeated annually to the same mainplots so that the

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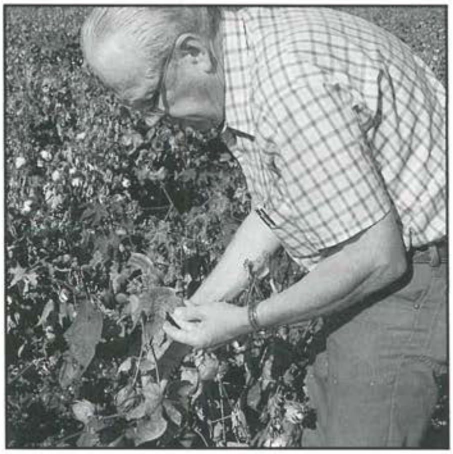
BRUCE ROBERTS, present Farm Advisor for Kings County, works with growers and researchers on K deficiency problems.



LES STROMBERG, Fresno County Farm Advisor Emeritus, recognized K deficiency in the 1950s.

cumulative applications for the last year (1987) were 0, 375, 750, 1,500 lb/A of K_2O.

There was a significant yield response to applied K each year (**Table 1**). Although lint yield of GC-510 was initially higher than SJ-2, yields of both varieties increased linearly as the rate of K increased. The variety Acala SJ-2 is the more sensitive to low available K and more responsive to added potash. Each year, yields of cotton receiving K fertilization were higher than the previous year . . . indicating appreciable benefit to carry-over K.

Fiber quality of both varieties was also improved by K fertilization. The benefits to quality were greatest the third year (**Table 2**), due to the cumulative effect of three annual applications of K. All parameters measured–length, micronaire, strength, elongation, and uniformity ratio–were improved. Also, each of these measurements was positively correlated with available soil K and plant tissue levels.

The seemingly small differences in fiber quality measurements can translate into lost profit for the grower. Cotton fiber which measures below set quality standards is penalized with price discounts. And with HVI, each bale is measured. Low quality fiber is a "hidden hunger" above and beyond that associated with yield.

More Improvements Down the Road?

Beltwide interest in K fertilization will continue as long as the goal of cotton

(continued on page 9)

Table 1. Annual K applications produce cumulative cotton yield increases.

Annual K_2O application, lb/A	1985		1986		1987	
	SJ-2	GC-510	SJ-2	GC-510	SJ-2	GC-510
	Lint yield, lb/A					
0	679	—	676	932	643	916
125	741	—	809	1,023	—	1,063
250	730	—	848	1,071	—	1,168
500	816	—	968	1,175	1,103	1,257
AOV: K rate	**		**	**	**	**

Avail. soil K: 0-8 in., 68 ppm (low); 8-16 in., 61 ppm (low); 16-32 in., 38 ppm (very low).

** Significant at P <0.01

— Signifies treatment omitted that year.

Manganese Deficiency in Alfalfa

By Joseph R. Heckman

In a recent survey of alfalfa fields in New Jersey, many were found to have tissue manganese (Mn) concentrations below 21 parts per million (ppm). These fields exhibited interveinal chlorosis typical of Mn deficiency. Although Mn deficiency is probably the most widespread micronutrient deficiency in crops grown on Atlantic Coastal Plain soils, it has not previously been recognized as a problem on alfalfa. The target soil pH and lime recommendations for alfalfa are generally higher than for other field crops. Changing soil acidity from many years of lime application may explain why Mn deficiency is becoming more common.

AN ON-FARM FIELD STUDY was initiated in June 1990 following the first cutting of alfalfa to investigate the problem of Mn deficiency. Treatments applied as manganese sulphate are shown in **Table 1.** Foliar treatments were applied between each cutting. The broadcast soil treatment was applied once, after the first cutting.

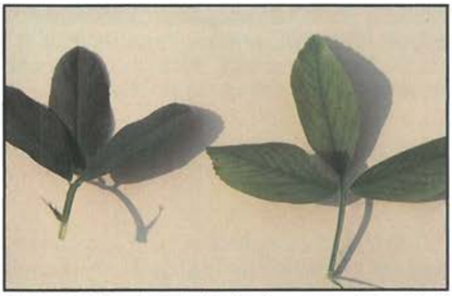
Table 1. Manganese treatments.

Mn Treatment	Time of application	Mn rate, lb/A per application
Check	None	0
Foliar, once	At 6-inch regrowth	1
Foliar, twice	At 6- and 12-inch regrowth	1
Broadcast	Once after first cutting	20

The effect of the Mn treatments on Mn concentration in alfalfa is shown in **Table 2.**

Table 2. Manganese fertilization influences Mn concentration in alfalfa tissue at early bloom.

Treatment	Rate per application, lb/A	Tissue Mn concentration, ppm 2nd cut	3rd cut	4th cut
Check	0	12.5	12.0	14.5
Foliar Mn, once	1	19.3	27.6	17.4
Foliar Mn, twice	1	36.3	107.8	30.7
Broadcast Mn	20	27.7	12.8	18.5
$LSD_{0.05}$		4.7	10.1	2.2



ALFALFA leaf at left is from a plot which received foliar Mn treatment. Leaf at right shows Mn deficiency.

The results show that foliar and broadcast Mn treatments were effective in increasing the tissue Mn concentration, but the broadcast Mn became less effective at latter cuttings. Manganese broadcast on the surface of a soil having a pH greater

Table 3. Yield response of alfalfa to applied Mn.

Mn Treatment	Rate, lb/A	Yield, tons/A 2nd cut	3rd cut	4th cut	Total yield, tons/A
Check	0	2.27	1.69	1.43	5.38
Foliar Mn, once	1	2.36	1.75	1.67	5.80
Foliar Mn, twice	2	2.31	1.81	1.53	5.65
Broadcast Mn	20	2.30	1.79	1.45	5.54
$LSD_{0.05}$		0.13	0.17	0.14	0.24

(Moisture = 15%)

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than 7.0 is apparently rapidly converted to unavailable forms.

Applied Mn increased forage yield only slightly for the second and third cutting (**Table 3**). In the fourth cutting, foliar applied Mn increased forage yield by an average of 12 percent.

Applied Mn also increased leaf chlorophyll content which resulted in visibly darker green plants. Foliar-applied Mn was more effective in increasing leaf chlorophyll than was broadcast Mn.

The first year's results of this study indicate that foliar applied Mn is more effective than broadcast. Manganese sulphate foliarly applied between cuttings at 1 lb/A of elemental Mn is an effective treatment for Mn deficiency in alfalfa. Additional research will be conducted to determine the best methods of Mn fertilization for new seedings and established alfalfa and to determine economic returns. ■

Cotton . . . from page 7

growers is to produce economical yields of high quality. Current research in several states is focusing on innovative application methods to improve the efficiency of K utilization. Deep placement has been very successful in the mid-south. In the west, research is being conducted with in-season water-run and sidedress applications. There is beltwide interest in supplemental applications of foliar K to improve yield and quality.

Cotton growers are long accustomed to closely monitoring the nitrogen status of their crops with soil analysis and tissue testing during the season. Prudent growers should be doing the same for K from now on. ■

Table 2. Cotton fiber quality improved with K fertilization.

Annual K_2O application, lb/A	Length, Inches	Micronaire index	Strength, g/tex	Elongation, %	Uniformity ratio
SJ-2 Variety					
0	1.10	3.23	27.5	5.1	0.80
500	1.13	3.76	29.5	5.7	0.81
GC-510 Variety					
0	1.11	3.85	27.7	5.7	0.82
500	1.12	4.21	29.1	6.2	0.83
AOV: K_2O rate	***	***	***	***	***

*** Significant at $P < 0.001$

Kansas

Effects of Sulphur Rates and Sources on Bromegrass

THREE YEARS of studies have shown a consistent yield response of bromegrass to applied sulphur (S) at two locations. Nitrogen (N) was applied at a constant rate of 120 lb N/A; S application rates were 15 and 30 lb S/A. Responses in 1990 produced good visual effects. April forage samples indicated significant increases in N and S concentrations from S applications. However, by harvest, N and S concentration differences had disappeared.

Researchers conclude that with current S, hay and beef prices, increases in forage production from S are economically viable. Producers who place heavy demands on their brome should give particular attention to S. ■

Source: R.E. Lamond, J.L. Davidson and D.A. Whitney. Published in Kansas Fertilizer Research Report of Progress 618: 22-23 (1990).

Fertilization Promotes Soil Organic Matter

By H. Henry Janzen

Long-term crop rotation studies in Alberta have shown that moderate applications of nitrogen (N) and phosphorus (P) fertilizer can increase surface soil organic matter contents and N supplying capability of western Canadian soils.

THE WELL-DOCUMENTED DECLINE in soil organic matter reserves has been identified as a serious threat to the sustained productivity of western Canadian soils. Organic matter is a vital constituent of these soils, serving not only as the major storehouse of nutrients, but also as an aggregating agent to reduce soil erosion and enhance moisture retention.

Long-Term Rotations

A long-term crop rotation study at Lethbridge, Alberta, provides a unique opportunity to determine the influence of cropping practices on soil organic matter. This experiment, established in 1912 shortly after initial cultivation of the soil, includes three cropping treatments: continuous wheat (W), fallow-wheat-wheat (FWW), and fallow-wheat (FW). Each phase of every crop rotation was established on a 1.6 acre plot. Beginning in 1967 and 1972, respectively, N and P applications, alone and in combination, were initiated on sub-plots at annual rates of 40 lb/A of both N and P_2O_5. All plots have been managed using full-scale farm machinery in accordance with recommended agronomic procedures.

Analysis of surface soil from selected treatments in this study demonstrated appreciable benefits of fertilizer application on organic matter characteristics (**Table 1**). In both the FWW and W rotations, fertilization with N and P increased organic carbon content by an average of 15 percent relative to the check after 18 years. In the FWW rotation, the increase was attributable primarily to N application, but in the W system, applying both N and P yielded a higher organic carbon content than application of N alone. The effects of fertilizer on organic N content were essentially identical to those on organic carbon.

Table 1. Fertilizer applications affect yield (1972-1984), soil organic matter content and quality (1984) in long-term spring wheat rotations.

Crop Sequence	Fertilizer lb/A N	Fertilizer lb/A P_2O_5	Yield, bu/A	Soil Organic C, tons/A	Soil Organic N, lb/A	Soil Mineralizable N, lb/A
FWW	0	0	18	7.0	1,385	148
	0	40	19	7.2	1,355	137
	40	0	20	8.2	1,522	203
	40	40	22	8.1	1,512	209
W	0	0	17	8.0	1,463	189
	0	40	19	7.9	1,385	217
	40	0	22	8.8	1,591	250
	40	40	26	9.2	1,679	246

Lethbridge, Alberta

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Fertilizer N application significantly increased the quantity of organic N in the soil, as well as its ability to release plant available N. The potentially mineralizable N content was calculated from the amount of plant-available N released from organic matter in a laboratory incubation. This value was, on the average, 33 percent higher in treatments receiving N fertilizer relative to those without N. These results suggest that application of N at moderate levels can sustain the organic N pool and prevent the need for much higher inputs in the future.

Several mechanisms can account for the positive effect of fertilization on organic matter characteristics. First, the content of organic matter in soil is directly related to the amounts of crop residues, including straw and root materials, returned to the soil. These materials are the precursors of organic matter. Application of fertilizer substantially increased grain yields and, concurrently, increased the amount of residues applied to the soil. Indeed, any factor which increases yields will tend to enhnace soil organic matter, provided that most of the organic materials (other than those in the harvested crop) produced are returned to the soil.

Controlled Environment Studies

In addition to increasing the amount of residues returned to the soil, fertilization may also increase the quality of those residues as a nutrient source. A greenhouse experiment at Lethbridge compared the N release from residues of wheat, lentil, and canola grown under three nutrient regimes differing in N fertility. In all cases, the higher the N nutritional status of the crop, the greater was the release of plant-available N from the residues (**Figure 1**). In part, the enhancement of mineralizable N content by N fertilization in the field experiment may be a reflection of the improved N status of the crop residues.

Improving the N status of the crop may also benefit soil organic matter and N fertility by stimulating N deposition from the roots via exudation and related processes. Controlled environment studies using ^{15}N tracer techniques indicated that N deposition by roots into the rhizosphere was more than twice as high when wheat was grown under high N fertility than under low N fertility. The N released into the rhizosphere was shown to be readily converted to plant-available form by microbial decomposition processes. This stimulatory effect of N application on N deposition into the soil may provide additional explanation for the enhancement of mineralizable N levels with N application.

Summary

Agronomic measures which ensure adequate crop nutrition are essential ingredients of soil conservation programs. Nutrient amendments in the range of economic yield responses are prerequisite to maintenance of soil organic matter reserves and sustained productivity. ■

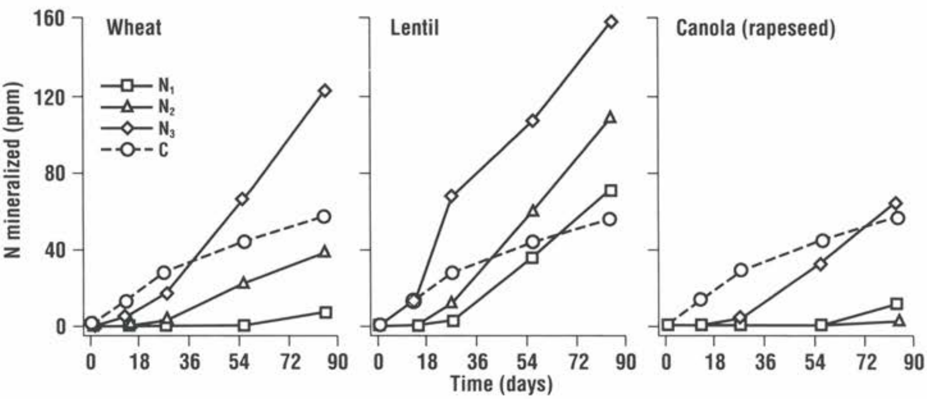

Figure 1. Crop and nutritional status affect N mineralization from crop residues (N_1 = low N; N_2 = moderate N; N_3 = high N; C = control, no residue).

Phosphorus and Potassium Uptake by Cotton

By G.L. Mullins and C.H. Burmester

Modern cotton varieties were studied to determine nutrient uptake and removal. Results indicate that dry matter and nutrient accumulation occurs earlier now than in older, later maturing varieties studied in the 1940s.

NUTRIENT ACCUMULATION by cotton grown without irrigation was last studied intensely in the U.S. during the mid-1940s. Recently, plant breeding has resulted in the development of improved cotton varieties that partition a higher percentage of their dry matter into the fruit as compared to older varieties. Nutrient accumulation may also be different in these improved cotton varieties.

Field studies were conducted in 1986 and 1987 to evaluate dry matter production and nutrient uptake by four genetically varied cotton varieties grown without irrigation. The varieties chosen were: Deltapine 90, an Acala cotton; Stoneville 825, a mid-south cotton from Delta breeding; Coker 315, a mid-south cotton from Carolina breeding; and Paymaster 145, a short season cotton developed mainly for the High Plains of Texas.

The test was conducted on a fertile Norfolk sandy loam soil in central Alabama and a fertile Decatur silt loam in north Alabama. Whole plant samples were harvested from each variety at two-week intervals throughout the growing season, beginning approximately 15 days after planting. The harvested plants were separated into leaves, stems and fruit for dry matter and nutrient analysis. The bolls were separated into lint, seed and burs. Squares, flowers and immature bolls were included in the bur fraction.

Dry Matter and Nutrient Accumulation

Surprisingly, this study showed that although these cottons were developed from genetically varied breeding, they were very similar in dry matter and nutrient accumulation. There were no varietal differences in total phosphorus (P) and potassium (K) uptake or P and K accumulation in specific plant parts. At the last sampling for each year, total P uptake from each soil was similar and averaged 15.4 lb/A. Phosphorus at the last sampling was distributed in stems 11.7 percent, leaves 19.5 percent, burs 16.0 percent and seed 52.8 percent.

Total K uptake averaged 88.4 lb/A on the Norfolk soil and 98.2 lb/A on the Decatur soil. Potassium at the last sampling was distributed in stems 24.8 percent, leaves 20.3 percent, burs 36.5 percent and seed 18.4 percent. Seed cotton yields were determined by mechanically picking the unsampled center rows of each field plot at the end of the season. They averaged 1,874 lb/A. Combining the yield data with the total P and K uptake determined at the final sampling for each year showed that an average of 2.5 lb P (5.7 lb P_2O_5) and 15.1 lb K (18.1 lb K_2O) were accumulated for each 100 lb of lint produced.

These uptake values are slightly higher than values previously published for

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irrigated cotton, but they are similar to values reported for non-irrigated cotton prior to the mid-1940s. We believe that the higher uptake values were due to late season drought conditions in both 1986 and 1987. The cotton plants in our study had accumulated enough P and K to produce higher yields, but late season fruit shedding reduced the yields actually measured. Therefore, nutrient uptake values per unit of lint were high. These uptake values apply to the conditions of our study and should not be interpreted as actual P and K requirements for cotton production.

Maximum Daily Nutrient Uptake

Maximum average daily uptake rates for P and K corresponded to the same time interval for maximum dry matter production. Depending on location and year, the peak two-week time interval for dry matter production occurred at 63 to 98 days after planting. This corresponded to the time when cotton began blooming until peak bloom. During this two-week period, daily uptake rates for P and K increased sharply. Uptake rates ranged from 0.28 to 0.55 lb/A/day for P (0.64 to 1.26 lb P_2O_5/A/day) and 2.0 to 3.1 lb/A/day for K (2.4 to 3.7 lb K_2O/A/day) during this period.

During the peak two-week intervals, an average of 30 percent of the total P and 35 percent of the total K was accumulated. For P, a secondary uptake peak occurred during boll formation.

Observations from this study indicated that for these modern varieties essentially all of the dry matter and all of the accumulated P and K was confined to the fruit at 100 days or more after planting. These results are in contrast to data from older, later maturing cotton from Georgia studies conducted during the early 1940s. The older data showed that cotton confined all of the dry matter production and nutrient accumulation in the fruit at 120 days or more after planting. **Figures 1 and 2** show P and K accumulation.

Summary

Dry matter production and nutrient accumulation by four modern cotton varieties were evaluated at two locations. Within a location, the four varieties produced and partitioned dry matter in a similar manner. The varieties also accumulated and partitioned P and K similarly. Seasonal accumulation of P and K by the cotton plants averaged 15.4 and 93.3 lb/A, respectively (35.3 lb P_2O_5 and 112 lb K_2O/A). Approximately one-third of the total seasonal uptake for each nutrient occurred during a two-week interval corresponding to the peak interval for dry matter production. The peak interval occurred between first and peak bloom when the vegetative growth was very rapid.

Our results show that an average of 52.8 percent of the total P and 18.4 percent of the total K accumulated by the plants were removed when seed cotton was harvested. ■

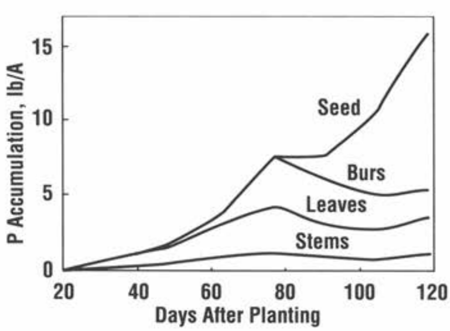

Figure 1. Uptake of P by four cotton varieties (averages) grown on a Norfolk soil (1986). Sampling was initiated at 21 days after planting and continued at 14-day intervals throughout the growing season. Reprinted by permission of the American Society of Agronomy.

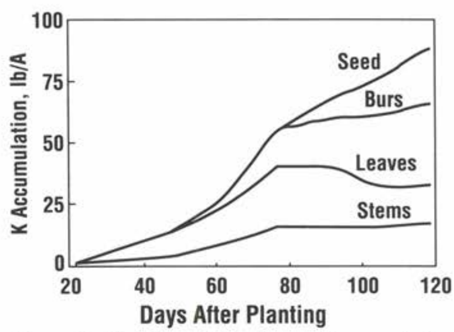

Figure 2. Uptake of K by four cotton varieties (averages) grown on a Norfolk soil (1986). Sampling was initiated at 21 days after planting and continued at 14-day intervals throughout the growing season. Reprinted by permission of the American Society of Agronomy.

Five Graduate Students Receive "J. Fielding Reed PPI Fellowships"

FIVE OUTSTANDING graduate students have been announced as 1991 winners of the "J. Fielding Reed PPI Fellowships" 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.

The 1991 recipients were chosen from nearly 40 applicants who sought the Fellowships. The five are:

- **Michel A. Beck, North Carolina State University**, Raleigh;
- **John A. Lory, University of Minnesota**, St. Paul;
- **Klaus P. Raven, Texas A&M University**, College Station;
- **Dale J. Tomasiewicz, University of Manitoba**, Winnipeg;
- **Kirsten Verburg, Cornell University**, Ithaca, New York.

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

"Each year, we have the privilege of presenting this recognition. All of the applicants for the Fellowships have excellent credentials," noted Dr. David W. Dibb, President, PPI. "These individuals and their educational institutions can take pride in the level of achievement represented."

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

Michel A. Beck

Michel A. Beck is a native of Basel, Switzerland. He received his B.S. degree at Virginia Polytechnic Institute and State University (VPI) in 1988. He is now completing his second year of graduate study in the Department of Soil Science, North Carolina State University. Mr. Beck's research objectives are to quantify changes in organic and inorganic soil phosphorus fractions and assess their levels of availability to plants under continuous cropping systems. Test soils to be used came from a field that was slashed and burned (from "virgin" tropical forest) in 1972 and has since been in a rice-soybean-corn rotation. His career goal is to be an active researcher, working in tropical soil fertility and crop production.

John A. Lory

John A. Lory was born in Pittsburgh, PA, and attended the University of Massachusetts before earning his B.S. degree in Agronomy at Cornell University in 1986. He received his M.S. degree in Soil Science from the University of Minnesota in 1990 and is now in a Ph.D. program there. Mr. Lory's dissertation title is "The Fate of Legume- and Manure-N in Alfalfa-Corn Rotations." The objective of his research is to utilize ^{15}N isotope to quantify manure-N movement in the soil, determine its use by alfalfa and ascertain the resulting reduction in N_2 fixation under field conditions of fall alfalfa establishment with spring applications of manure. He plans a career in which he can utilize expertise he is gaining in both Extension and research.


Klaus P. Raven

Klaus P. Raven was born in Lima, Peru, and attended Universidad Nacional Agraia-La Molina in Lima. He received his B.S. degree in Agronomy in 1984 and his M.S. degree in Soil Science in 1988. Since August of 1988 he has been a Ph.D. candidate at Texas A&M University. Mr. Raven's research is evaluating those factors which determine the phosphorus supplying power of soils. It will include laboratory and greenhouse studies, using several Texas soils, enriched with varying levels of phosphorus. Field data will be available to allow the evaluation of laboratory and greenhouse data in regard to phosphorus availability to crops. He plans a career in research, perhaps to include teaching, at a university or research institution.


Dale J. Tomasiewicz

Dale J. Tomasiewicz, born in Outlook, Saskatchewan, earned his B.S.A. degree with high honors (1979) and M.Sc. degree (1982) in Soil Science at the University of Saskatchewan. He is currently working toward a Ph.D. degree in soil science at the University of Manitoba. His research deals with plant responses to phosphorus nutrition stress and use of the responses in assessing soil phosphorus supplying characteristics. His work is better defining the nature of yield-limiting phosphorus stress in the field for wheat, utilizing various measures of plant tissue phosphorus during the growing season. Results will be applied to the study and assessment of plant availability of soil phosphorus. He plans a career that will include work with a broad spectrum of agriculturists, perhaps in a research role, in the area of soil chemistry/fertility and plant nutrition.


Kirsten Verburg

Kirsten Verburg is a native of Zaandam, The Netherlands. She received her M.S. degree with honors in Physical Geography and Soil Science at the University of Amsterdam in 1990. She is currently studying for her Ph.D. degree in Soil Science at Cornell University. Her dissertation is titled "Effect of Binary Exchange Hysteresis on the Availability of K in Soils." Her work plan consists of laboratory experiments and mathematical modeling to try to determine why exchange reactions involving heterovalent cations or specific pairs of monovalent cations are hysteretic (nonreversible). After completing her Ph.D. degree, Ms. Verburg hopes to do postdoctoral studies, eventually working full-time at a university or research institute. She favors a university appointment because it would also offer her the opportunity to teach and supervise students.

The Fellowship winners are selected by a committee of individuals from PPI staff and the PPI Advisory Council. The Fellowships are named in honor of Dr. J. Fielding Reed, retired President of the Institute, who now lives in Athens, Georgia.

Dr. W. R. Thompson, Jr., PPI Midsouth Director, served as chairman of the selection committee for the 1991 Fellowships. ■

Characteristics of Phosphate-Deficient Soybeans

By Dale G. Blevins

Phosphorus (P) deficiency in plants is difficult to identify visually. It is associated with many essential biochemical reactions. Phosphorus affects the carbon dioxide (CO_2) assimilation rate of soybeans, which could cause varying metabolic and physiological reactions, depending on shortage severity.

PHOSPHORUS DEFICIENCY in plants is associated with many biochemical reactions that are necessary for plant life and reproduction. Phosphorus has a key role in the following biochemical processes:

- ATP and ADP–the most common energy "currency" found in plants;
- Photosynthesis–the conversion of light into simple sugars;
- Electron transport–oxidation and reduction reactions within the plant;
- Sucrose transport–the movement of sugars through cell membranes;
- Glycolysis–for metabolism of carbohydrates under anaerobic conditions.

There are many other metabolic and biochemical processes in which P is involved, and many more are being discovered through continuing research.

Deficiency Symptoms

Phosphorus deficiency symptoms in plants can be difficult to distinguish. Deficiencies are often hard to identify visually. Some symptoms in soybeans that can be determined by close observation include:

- Reduced number and size of root nodules;
- Spindly, small diameter stems;
- Small dark-green or bluish leaves;
- Leaflets may curl upwards;
- Delayed plant maturing and reduced yields.

Orientation of Soybean Leaves to Light Under High and Low P Conditions

A recent study under controlled conditions investigated physiological responses of soybean leaves to low P conditions. Photosynthetic responses to light and CO_2 were examined in leaves of soybeans grown under high and low phosphate conditions. In millimolar (mM) units, 0.50 mM was considered high and 0.05 mM low.

Leaves of plants grown under high and low P conditions were photographed to monitor how they tracked and intercepted the sun's light. The photographs show that soybeans grown under adequate P nutrition can rotate their leaves during the day to maximize the interception of light. Soybeans grown under low P conditions had great difficulty in orienting their leaves toward the sun's light.

Response of Net Assimilation Rate to Light

Phosphorus influenced the overall net CO_2 assimilation rate of soybeans using several detailed measurements (**Table 1**). The photos demonstrate that soybeans grown under low P conditions would be expected to have a lower net CO_2 assimilation rate. That was confirmed by the differences in photosynthetic rates between the two treatments (**Table 1**).

The low carboxylation efficiency of the low P treatment indicated that carbon

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Soybeans with adequate P nutrition. Soybeans with low P nutrition.

Early Morning


Mid-Day


Late Afternoon


SOYBEANS grown with adequate P nutrition (left column) can rotate their leaves during the day to maximize the interception of sunlight. Soybeans grown with inadequate P nutrition (right column) have difficulty orienting their leaves toward the sun's light and are less efficient.
(Photos courtesy Lauer and Blevins).

Soybeans . . . from page 17

Table 1. Summary of P effects on assimilation rate versus internal CO_2 content of soybean leaves, carboxylating enzyme (Rubisco) specific activity and specific leaf weight.

	Treatment, mMP	
Variable	High P 0.50 mM	Low P 0.05 mM
Photosynthetic rate (at 34 Pa CO_2; $\mu mol/m^2/s$)	19.5[1]	6.7**
Carboxylation efficiency ($\mu mol/m^2/s/Pa$)	2.90	0.49**
Internal CO_2 partial pressure (at 34 Pa external CO_2; Pa)	15.9	26.2**
Carboxylating enzyme (Rubisco), specific activity ($\mu mol/m^2/s$)	25.0	16.7**
Specific leaf weight (mg/cm^{-2})	2.97	4.06**

[1]Data are the means of three separate experiments with a total of eight replications.
**Denotes significance at the 0.01 confidence level.

fixation at low internal CO_2 concentrations (in the stomates) was not functioning as efficiently as in high P treatments. The greater carboxylation efficiency of leaves of the high P treatment may explain the lower internal CO_2 partial pressure of 15.9 Pa compared with 26.2 Pa for the low P leaves.

There was also a significant difference in the specific activity of the carboxylating enzyme, Rubisco, between the treatments. The lower P treatment decreased the specific activity of Rubisco 33 percent. As plants of both treatments were dependent on fixed nitrogen (N), specific activity of Rubisco should have been comparable unless the enzyme itself was affected by the treatment.

It is also interesting that the lower P treatment increased the specific leaf weight (SLW) of soybeans. The SLW was increased 37 percent at the lower P treatment, indicating a thicker leaf.

Conclusions

These data show that soybeans respond metabolically to P stress with reduced photosynthetic rates, lower carboxylation efficiencies, higher internal CO_2, and reduced Rubisco activity.

Physiologically, soybeans respond to P stress with reduced ability for solar tracking by leaves and thicker leaf structures.

A soybean plant's metabolic and physiological reaction to P shortages may vary significantly depending on the severity of the shortage. Research, however, has shown that P shortages do affect these processes by reducing the plant's efficiency and increasing the probability of lower yields and lower profits for farmers. ■

Missouri

Potassium Fertilizer and Potato Leafhopper Effects on Alfalfa Growth

POTASSIUM (K) is known to alter a plant's resistance to environmental stresses such as diseases and drought. In two glasshouse experiments, researchers assessed the effects of K fertility on potato leafhopper (PLH) feeding on mature and young alfalfa plant growth, regrowth and carbohydrate reserves. Plants were grown on two topsoils, the mature ones on a loam, the young ones on a clay. Each was treated with the equivalent of 0, 100, 200 and 400 lb/A K_2O.

Herbage growth, shoot height, net weight and total nonstructured carbohydrates were increased by K fertilization. Susceptibility to PLH injury was greatest with the young alfalfa plants. Increasing the K fertility did not reduce PLH injury in alfalfa. However, both growth and persistance improved, with or without PLH, with increasing K fertility. ■

Source: N.R. Kitchen, D.D. Buchholz and C.J. Nelson. Published in Agron. J. 82:1069-1074 (1990).

Phosphorus: An Alternative to Liming Acid Wheatland Soils

By Randal K. Boman, Robert L. Westerman and Gordon V. Johnson

The following article presents some of the initial findings of a two-year study on how phosphorus (P) can affect wheat forage and grain yields on acid soils. The authors report significant findings on P fertilization and its implications on beef cattle gains and nutrition. Future articles will update information from this important research.

HARD RED WINTER WHEAT is the main cultivated crop in Oklahoma. It is grown for forage, for grain, or, when livestock are removed from pasture by early March, for both forage and grain. Dryland wheat is most intensively managed in the central part of the state, where average annual rainfall is 25 to 35 inches. The region extends into Kansas and Texas and is characterized by moderately fertile, dark brown and reddish-brown soils, some of which are acid.

Soil Acidity and Wheat

Records indicate that selected soils of this region were acidic when first cultivated 40 to 60 years ago. However, intensive management including high rates of applied nitrogen (N) and harvest of high yields has promoted development of extreme soil acidity. **Table 1** shows the amount of basic cations (lime-like materials) removed

Table 1. Basic cations removed by grain and straw of a 30 bu/A wheat crop.

	Ca	K	Mg	Na	Total
			------lb/A-------		
Grain	2	10	10	2	24
Straw	11	45	14	9	79
Total	13	55	24	11	103[1]

[1]1 ton alfalfa will remove slightly more than this amount.

EXTREME SOIL ACIDITY can have devastating effects on wheat yields. The area in the center of this photo had a soil pH of 4.7. Areas to the right and left had been limed.

The authors are in the Department of Agronomy, Oklahoma State University; Randal K. Boman is Senior Agriculturalist, Dr. Westerman is Regents Professor and Department Head, and Dr. Johnson is Professor of Agronomy.

annually by modest wheat yields. Many wheat producers have been surprised to find that wheat pasture or straw removal will contribute to soil acidity three or four times faster than grain production alone. This is because leaves and stems are very high in potassium (K) and other nutrients which work against the development of soil acidity.

Soil testing is commonly used by wheat producers. However, because lime sources are frequently 50 to 100 miles away, producers did not lime fields when soil tests initially indicated the need. With time, soil pH continued to decline to values as low as 4.0 and below. Some fields failed to produce a crop when soil pH was about 4.3. Others seemingly were unaffected at pH values below this apparent critical level. Varieties were proven to differ in tolerance of soil acidity.

Oklahoma research identified that aluminum (Al) toxicity to seedling wheat was the major cause of crop failure at extremely acid soil pHs. A common practice among producers successfully growing wheat in very acid soils was application of P fertilizer with the seed at planting time.

Phosphorus in Acid Soils

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, as P is fixed so, too, is Al, since each is part of the unavailable aluminum phosphate material formed. This "fixing" of Al in the seedling root zone partially explains why farmers who apply phosphate fertilizer with the seed can produce normal wheat yields without liming.

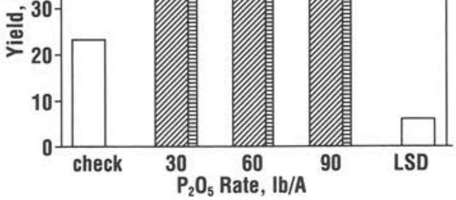

Figure 1. Effects of P banded with the seed on wheat grain yield on a strongly acid soil.

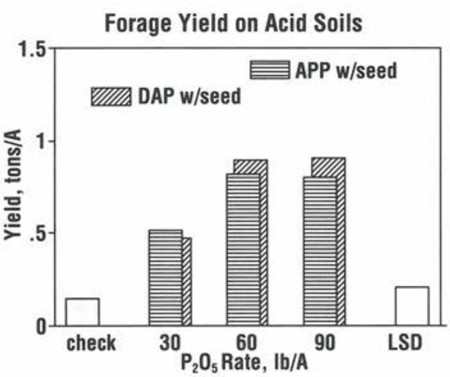

Figure 2. Effect of P banded with the seed on wheat forage yield on a strongly acid soil.

Research Results

In the last two years, research conducted by Oklahoma State University has examined effectivenesss of P fertilizers and P rates for wheat on very acid soils. Preliminary results of these studies conducted on producers' fields are illustrated in **Figures 1 and 2**.

The effectiveness of P fertilizer banded with the seed on grain yield is indicated in **Figure 1**. Banded P applications were substantially more effective than broadcast applications. Soil pH was 4.8 at this site and the Mehlich III P soil test index was 148 (very high). A soil test index of 65 indicates adequate P for normal wheat production. In order to regain normal production from liming, a rate of 1.2 tons/A of effective calcium carbonate equivalent (ECCE) lime would be required. Without that treatment (check) the grain yield was about 25 bu/A. When a rate of 30 lb/A of P_2O_5 was applied with the seed, yield was increased to about 40 bu/A. Higher rates of P did not increase yield further in the first year of the study. Diammonium phosphate (DAP), monoammonium phosphate (MAP), and ammonium polyphosphate (APP) were equally effective.

Seed-placed P had tremendous effects on wheat forage yields under the same acid soil conditions in the first two years' data (1990 and 1991). Without P, there was not enough forage to support a wheat pasture program. The 60 lb/A P_2O_5 rate produced a five-fold increase in forage yield. The maximum yield represents a 0.7 ton forage increase compared to the check. There were no significant differences among P sources. Forage response to the additional 30 lb/A P_2O_5 is related to the need for early season growth for a grazing program. Grain production, however, is not as strongly influenced by fall growth.

Banded P applications were highly economical. In these experiments, each 30 lb of P_2O_5 cost about $7.50. The grain yield increase of 15 bu/A, even in a depressed market, would have a value of at least $30.00 for a 4 to 1 return from P. The increase in forage production from 60 lb/A of P_2O_5 ($15.00) would support about 140 lb of beef gain worth more than $112.00 for about a 7 to 1 return from fertilizer.

Liming is a practical and usually economical solution to the acid soil problem, especially for fields that already supply adequate P. For this study, 1.2 tons of ECCE lime would have cost about $30.00/A applied and would last about five years. To maintain maximum yields for five years using P placed with the seed would cost approximately $37.50/A for grain production and $75.00/A for pasture. Obviously, the best approach to sustained yields is to lime and supply adequate P.

Summary

Phosphorus fertilizer, placed with the seed, is an effective alternative to liming strongly acid soils for winter wheat production. When wheat is managed for forage, the required P rate is higher because early fall growth is critical. Using P fertilizer instead of liming is economical when lime costs are high and when production is considered on a year-to-year basis. In those instances, where P fertility is already high, standard liming practices will provide the best long-term economics. The importance of P in wheat grazing systems for this region must be recognized for top profitability of cattle-wheat operations. ■

California

Potassium Nutrition Effects on Lint Yield and Fiber Quality of Acala Cotton

TO EVALUATE the relationship between the potassium (K) status and fiber quality of cotton, researchers studied the effect of K fertilization on one cotton cultivar in 1985 and on two cultivars in 1986 and 1987. The cultivars were grown on an irrigated vermiculitic soil and were fertilized with the following rates of K_2O: 0, 100, 200 or 400 lb/A.

There was a significant seed-cotton yield response to applied K each year. Lint yield increased relatively more than seed yield, resulting in a greater lint percentage as the K supply increased. Although increased plant K supply resulted in higher lint quality in both cultivars, the relationship among fiber quality and fiber, leaf, or soil K status was considerably different for the two cultivars.

Researchers concluded that K supply to cotton fruit is an important determinant of fiber quality, and that the K requirement for producing high lint yield with acceptable quality may differ among genotypes. ■

Source: K.G. Cassman, T.A. Kerby, B.A. Roberts, D.C. Bryant and S.L. Higashi, University of California. Published in Crop Science 30(3): 672-677 (1990).

The Time Is Right for MEY

By Ron Olson

We can protect the environment without compromising profitability in crop production.

DURING THE 1980s, the concept of maximum economic yield (MEY) was sometimes viewed negatively because its critics often ignored the "E" and focused only on "maximum yield." However, I believe the power of an idea can often be measured by the resistance it receives. MEY has proven to be a powerful idea.

Today, with environmental concerns at an all time high, the MEY concept spells opportunity for farmers. That's because MEY principles promote **least-cost** crop production. MEY actually has a dual meaning. It can just as easily stand for maximum **environmental** yield because the very concepts which promote efficient and profitable crop production are those which are most environmentally sound. For a farmer to reach MEY, he must pay attention to agronomic details on every acre of his farm and make efficient use of all inputs and resources.

For the past decade, we have worked with dealers and other interested parties in establishing MEY groups. These associations are designed to open doors to new concepts which can increase the efficiency and profitability of crop production. While the concept of MEY was first accepted by innovative farmers, it has since come into its own. In the past, some farmers resisted the concept of managing each acre as an individual ecosystem. Today, environmental concerns have resulted in a shift in attitudes . . . MEY concepts are now accepted by most mainstream farmers

MEY groups offer the opportunity to receive new, often unique, information. Cost control and environmental responsibility are key issues for today's farmers and MEY groups can allow you to address these twin concerns.

For example, a common objective among our MEY groups is to fine-tune nitrogen (N) management to the point where one bushel of corn is received for each pound of N applied. Realistic yield goals are set, soil tests and plant tissue analyses are conducted, and residual N is accounted for. When all pertinent data are "crunched", recommendations are fine-tuned. A common denominator among growers hitting optimum yields has been the use of N stabilizer. MEY concepts cover the realm of cropping inputs, not just fertilizer. Integrated pest managenent (IPM) and prescription recommendations are all part of a successful MEY experience. It's a systems approach–a process designed to produce the desired outcome: profitable yields.

MEY groups also provide excellent training opportunities. MEY concepts force you to step away from the comfort zone that can form over time and force you to synthesize new technology into practical applications. This serves to hone technical, agronomic and communication skills.

Best management practices (BMP), sustainable agriculture, or maximum economic (environmental) yield–regardless what name you prefer, they all represent related concepts designed to produce optimum yields for maximum profitability. The MEY groups are simply a tool for formalizing these concepts into a package to benefit you and your operation.

Environmental legislation and support for sustainable agriculture may make least cost production a burden rather than an opportunity. We must ensure these concepts do not inhibit our ability to grow profitable yields. By joining MEY groups, utilizing available management programs and focusing on the "E" in MEY, we can protect the environment without compromising profitability. The time is right for MEY. ■

Mr. Olson is Vice President of Top-Soil Testing Service, Inc., Frankfort, IL.

Beef Up Wheat Pastures with Phosphorus

By J. Larry Sanders, Robert L. Westerman, and Arthur B. Onken

Improved phosphorus (P) management for wheat in much of the Great Plains and Southwest could provide dramatic increases in forage yields for cattle grazing, as well as higher grain yields.

RANCHERS and beef producers have made great strides in improving the genetic potential of their beef cattle herds. As herds have continually improved, however, the management of forages has not kept the same pace.

Phosphorus deficiency has been recognized as the most prevalent nutrient deficiency of cattle and sheep in the U.S. Data from Texas (**Table 1**) show that providing additional P through supplements or range fertilization can significantly affect weaning weights of calves.

Table 1. Phosphorus-fertilized range increases weaning weights.

Group	lb weaned calf/A
Control, no supplemental P	93
Bone meal supplement	116
Disodium phosphate in drinking water	143
P fertilized range	176

Texas

☞ Fertility Pointer: Note that when P is supplied through the forage, recorded weaning weights were highest. Range fertilization is the easiest and best way to supply P to cattle.

Animal Nutrition and Phosphorus

About 80 percent of the P in the animal body is found in the skeleton. The major structural role of P is as a constituent of bones and teeth. It is also essential in the proper utilization of energy in animal nutrition. It is **present in every living cell** and important in all phases of reproduction.

Phosphorus deficiency and appetite. The earliest symptoms of P deficiency are decreased appetite, lower blood P and reduced rate of gain. In dairy cattle, milk

IMPROVED MANAGEMENT of wheat as forage offers opportunity for beef producers in the Great Plains and Southwest.

Dr. Sanders is Great Plains/Southwest Director of the Potash & Phosphate Institute (PPI), located at Stanley, Kansas. Dr. Westerman is Regents Professor and Head, Department of Agronomy, Oklahoma State University. Dr. Onken is with Texas A&M University.

Pastures . . . from page 23

production decreases. Efficiency of feed utilization is depressed. These effects are followed by a **reduced appetite**. Long-term P inadequacy results in bone changes, lameness, and stiffness of joints. Bone fractures may occur.

Improve Wheat Forage Yield and Quality with Phosphorus

Wheat forage responds to P under irrigated conditions. Texas data indicate that both wheat pastures and wheat grain yields respond well to fertilizer P. **Table 2** shows that wheat forage yields can be quadrupled with adequate nitrogen (N) and P fertilization. Total forage yields were increased from 670 to 2,877 lb of dry forage per acre.

Soil tests predicted the need for additional fertilizer P in this study and can be an important tool in determining when low soil P is limiting wheat growth . . . and profits.

Grain yield responses to both N and P were greater for areas that were clipped (grazed) than unclipped. Yield increases were obtained up to rates of 240 lb fertilizer N/A at the 40 and 80 lb P_2O_5/A rates. The interactions of N and P indicate that maximum grain yield for this soil, where forage was removed, may require P_2O_5 application rates even higher than the maximum 80 lb/A applied.

Table 2. Adequate N and P are essential for wheat forage and grain yields.

Fertilizer rates, lb/A		Oven dry forage,[1] lb/A	Grain yield[2], bu/A	
N	P_2O_5		Unclipped	Clipped
0	0	670	28	22
120	0	1,372	70	81
160	0	1,372	72	72
240	0	1,410	55	84
120	40	1,915	60	66
160	40	2,303	92	99
240	40	2,418	78	105
120	80	2,117	86	92
160	80	2,318	85	118
240	80	2,877	67	88

Variety: TAM 105. Texas

[1]Total of two clippings to simulate grazing.

[2]Eleven percent moisture.

☛ Fertility Pointer: Rates of N and P required for maximum forage (and grain) production may be greater than those applied in this study.

Wheat forage responds to P under dryland conditions. In Oklahoma, under conditions of low pH and aluminum (Al) toxicity, application of P fertilizer appears to reduce Al toxicity problems and results in increased forage and grain yields.

Oklahoma research has recorded a five-fold increase in forage yields and essentially a doubling of grain yields from

WHEAT with 60 lb/A P_2O_5 band-applied yielded five times more forage and almost twice as much grain as control plots with zero P_2O_5 (Oklahoma).

Table 3. **Fertilizer P is extremely important for wheat forage and grain yields on acid 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

Very high P soil test. Soil pH = 4.5. Oklahoma

☞ Fertility Pointer: Wheat forage and grain yields both responded to increased P rates even under very high P soil test on acid soils. Researchers suspect that P is detoxifying Al that interferes with wheat root growth and yields of forage and grain.

increased P availability from fertilizer P applications (**Table 3**). Banding fertilizer P instead of broadcasting almost doubled forage yields in both years of the study. There were no significant differences in efficiency of three P sources.

Kansas data show that in addition to increased forage and grain yields, adequate P fertilization can have significant effects on the P concentration in wheat plants during the grazing period. Data in **Table 4** show how plant P concentrations at five locations across the state increased with application of fertilizer P on low testing soils. Texas data in **Table 1** imply the importance of higher plant P concentrations for calf weaning weights.

Table 4. **Fertilization with adequate P boosts wheat forage P concentrations.**

Rate of fertilizer P lb P_2O_5/A	Wheat plant P concentration, % Site 1	Site 2	Site 3	Site 4	Site 5
0	0.21	0.17	0.18	0.20	0.24
40	0.26	0.25	0.24	0.28	0.27
Soil test P:	Low	Low	Low	Low	Low

75 lb N/A Kansas

The Connection: Beef/Wheat Pasture/Phosphorus

It's not productive to select superior stocker cows to run on P-deficient wheat pastures. Remember that cattle can't hang beef on a poorly developed, P-deficient carcass.

Phosphorus soil test summaries indicate that from 50 to nearly 70 percent of the soils in the Great Plains and Southwestern region test medium and lower in soil P (**Figure 1**). This is a major winter wheat grazing area where P nutrition of plants and animals is a great concern. Supplying needed P benefits all segments of the system ... better growth of wheat forage, higher grain yields, and better rates of gain for cattle grazing wheat forage. All of those factors add up to the final equation ... higher profits. ■

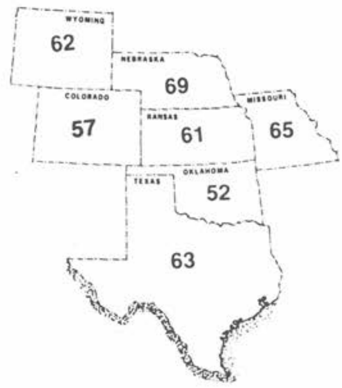

Figure 1. **From 50 to nearly 70 percent of soils in the Great Plains and Southwest test medium or lower in soil P.**

Optimum Phosphorus Management for Small Grain Production

By Paul E. Fixen and Ardell D. Halvorson

In many respects, economic evaluation of phosphorus (P) management is more complex than nitrogen (N) management. This is due to the substantial residual value of P fertilizer applications. Also, P soil tests are indices which reflect the average relative yield or probability of response at a given level. They frequently do not accurately predict the precise rate of P necessary to give a certain yield in any given season. This uncertainty has led to debates by agronomists on how to best use P soil tests. Typically these debates go unresolved with differences attributed to the "philosophical" positions of the individuals.

PART OF THE CHALLENGE in economic evaluation of P management is dealing with variable responses. **Figure 1** summarizes several long-term spring wheat studies from the northern Great Plains and is typical of P calibration data. At a 20 lb/A P soil test, relative yield varies from 70 percent to 100 percent (100 percent is defined as the estimated yield with P non-limiting). At a 10 lb/A soil test (**Table 1**), a grower who does not apply P could expect to lose from 7 to 15 bu/A, depending on average yield potential, due to inadequate P availability. However, the actual P response varies widely from year to year.

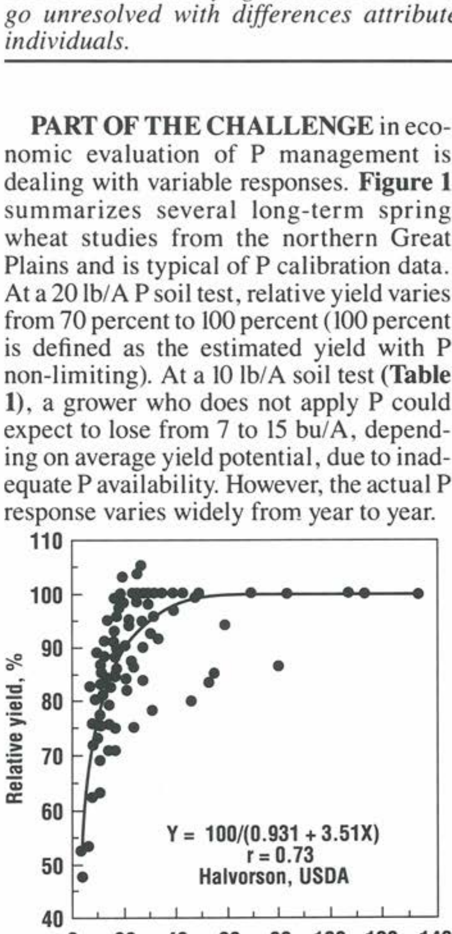

Figure 1. Spring wheat response to soil test P level in the northern Great Plains.

Table 1. Estimated spring wheat yield loss from P deficiency at various soil test levels.

Olsen P, lb/A	Relative yield, %	Average yield potential, bu/A: 30	50	70
		bu/A lost		
10	78.0	6.6	11.0	15.4
20	90.4	2.9	4.8	6.7
30	95.4	1.4	2.3	3.2
40	98.2	0.5	0.9	1.3
50	99.9	0.0	0.1	0.1

Based on data from Figure 1. Halvorson, USDA

Response variability to fertilization at a given soil test P level should not be surprising. Numerous factors other than soil test level influence supplemental P needs in a given growing season on a given soil type. Variability in P response among years and the nature of P soil tests suggest that response economics should be viewed in the long term.

Economic Evaluation of P Management

Nearly all P fertilizer recommendation systems maintain soil tests at some level either intentionally or incidentally from rates recommended for various yield goals. However, systems vary in the rate and extent of build-up. A critical question is: At what level should P soil tests be maintained? This question can be addressed

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economically. It can be viewed as independent of maintenance costs as long as the costs of the maintenance nutrients are subtracted from the value of the crop grown. A bushel of wheat grain contains about 0.5 lb of P_2O_5 at a value of approximately 11 cents.

Only a fraction of the P_2O_5 applied in any one year is used by the crop in that year. In most soils, the majority of P_2O_5 applied remains in the soil in forms that are available for future uptake. Just as costs of installing tile drainage or irrigation are not recovered in one year, the cost of build-up P does not need to be recovered in one year, even though this can happen.

The cost of build-up applications should be amortized over several years ... the expected lifetime of the investment or the expected time of ownership. Since build-up P should never wear out if removed nutrients are replaced, expected time of ownership or operation would normally be the controlling factor. Therefore, land tenure becomes an important factor in determining the target soil test level.

Amortization requires use of an interest rate. This could be the interest associated with borrowed capital or viewed as an opportunity cost for alternative investments if no money is borrowed.

Long-term crop and fertilizer prices will influence selection of a target soil test level. Also, the amount of P_2O_5 required to change the soil test level a given amount impacts the cost of soil P build-up.

Since soil tests are usually related to relative yield in percent, the average yield potential of the field is another factor to consider. The higher the absolute yield, the greater dollar value each percent increase in relative yield will have.

Obviously, a number of factors influence the optimum soil test level for a given field. One must decide the importance of each of these factors and how they interact with each other. The best way to discuss these factors is to select an appropriate data set and evaluate the effect of various conditions on the optimum soil test P level.

Factors Influencing Optimum Soil Test Levels

The percent yields in **Figure 1** were converted to bushels per acre **(Table 1)** since economic evaluation requires absolute rather than relative yields. A relative yield of 95 percent has commonly been viewed as essentially the same as maximum yield. However, an **actual** long-term average yield reduction of 5 percent can be of substantial economic importance to a farmer ... and important when considering P because of the relatively inexpensive nature of P build-up.

A computer program was developed, based on the equation in **Figure 1**. It will calculate the P soil test level at which the amortized cost of an additional unit of soil test build up is equal to the average value of the additional yield increase. The following discussion is based on that program.

Average yield potential and land tenure have dramatic effects on optimum soil test level (STL) **(Figure 2)**. The three curves represent 30, 50 and 70 bu/A average yield potentials. As land tenure increases, optimum soil test level increases. Land operated on a short-term lease has a lower optimum level than land that is owned and likely to stay in the family for decades.

Fertilizer price, crop value, and interest rates also influence optimum soil test levels, but not as much as yield potential and land tenure. For example, increasing net wheat price from \$2.50 to \$3.50/bu increases optimum soil test level by only 5 to 8 lb/A.

Soils differ in the amount of P required

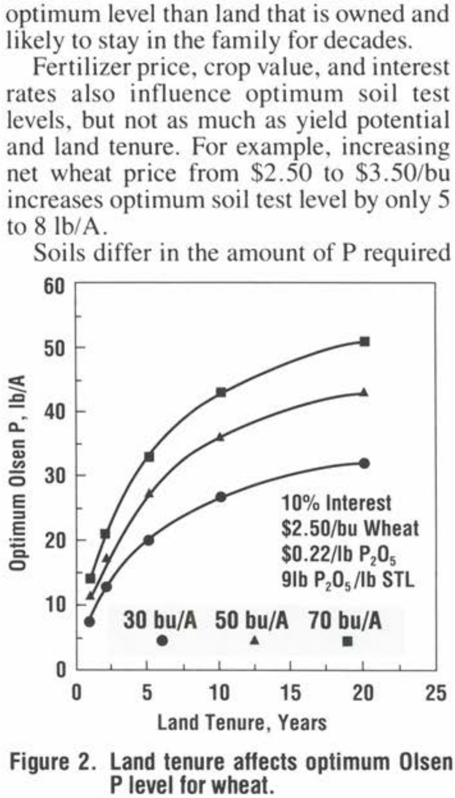

Figure 2. Land tenure affects optimum Olsen P level for wheat.

to change soil test levels (P buffer capacity). Some low pH and some high pH soils fix applied P_2O_5 readily and build-up is more costly, decreasing the optimum soil test level. Many soils require from 8 to 12 lb P_2O_5 to change the soil test P level one lb/A.

Determining Optimum P Rates

When a long-term basis is used in making P rate decisions, the focus must be on soil test P level. Therefore, the first step in determining optimum rate must be determination of optimum soil test level considering the factors discussed earlier. Then, a rate-soil test level relationship needs to be used that maintains soil test levels at the optimum point. In other words, if the current soil test level is less than the optimum, the rate should be greater than the quantity of P removed by the crop to allow soil test levels to build. If the current level exceeds the optimum, the rate should be less than removal which will allow soil test levels to decline to the optimum point.

A critical question is: How fast should a low testing soil be built to the optimum level? In most cases it makes little economic sense to apply P at a rate that exceeds the rate required for maximum yield during the year of application. The following example illustrates how that rate can be estimated.

Given:	
Current P soil test level:	5 lb/A
Relative yield (Figure 1):	61.2%
Yield with P nonlimiting:	50 bu/A
P (P_2O_5) uptake by plants:	
Total: 0.68 lb P_2O_5/bu × 50 bu = 34 lb P_2O_5	
From soil:	21 lb (61.3%)
From fertilizer:	13 lb (34-21)

In this example, 13 lb P_2O_5 must come from the fertilizer for the crop to yield its full potential of 50 bu/A. In order to know how much fertilizer to apply, the first year recovery of fertilizer P by the crop must be known or assumed. Recovery the year of application at low soil test levels can vary from less than 10 percent to as high as 30 percent. As soil test P levels increase, response to P fertilization decreases and recovery declines.

The best we can do in our general example is to illustrate rate requirements at high and low first year recoveries as follows:

30% recovery: 13 lb P_2O_5 needed/0.30 =
43 lb P_2O_5 to apply

15% recovery: 13 lb P_2O_5 needed/0.15 =
86 lb P_2O_5 to apply

Fertilizer placement and growing season weather conditions are major factors determining P recovery. Recovery at low soil test levels and modest application rates will usually be higher for band than for broadcast applications. Above Olsen P levels of 25 to 30 lb/A, band and broadcast applications generally have similar effectiveness. However, environmental conditions can cause enhancement of early growth and development by seed-placed P_2O_5 even at high soil test P levels.

Recommended rate of applied P would decrease as soil test level increases above 5 lb/A until application equals removal at the grower's optimum soil test level. If the grower in the example had an optimum soil test P level of 25 lb/A (10 percent interest, 4-year tenure, 9 buffer potential, \$0.22/lb P_2O_5, \$2.50/bu), crop removal or 25 lb P_2O_5/A (0.5 lb P_2O_5 removed/bu) would be applied at that level.

A single application of 86 lb P_2O_5/A, indicated for the lower first year recovery in the example, will normally increase soil test levels by 6 to 9 lb/A. That will result in a reduction in future P_2O_5 needs and greater placement flexibility.

The fit of the approach outlined can best be evaluated by using data shown in **Figure 3**. It indicates the average wheat

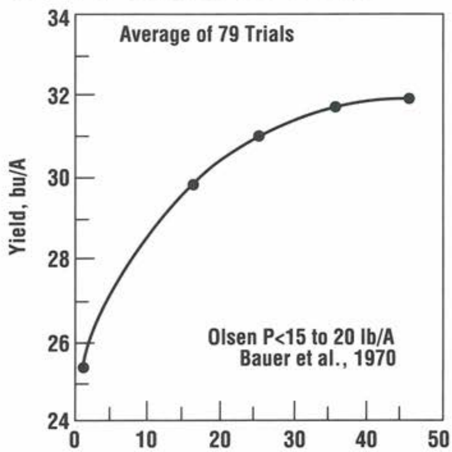

Figure 3. Wheat response to banded P (North Dakota, 1949-1961).

response to rates of banded P from 79 trials conducted in North Dakota from 1949 to 1961 where soil P tests were less than 20 lb/A. These historical data show some yield response up to 45 lb banded P_2O_5 and are supportive of the rates calculated where high first year recovery is assumed. Rate requirements today are likely to be at least as high at a given soil test level as they were in the 1950s.

A Long-Term Look at P Rates, Placement, and Yields

To maximize profitability, long-term effects cannot be ignored in P fertilizer management. Researchers in Saskatchewan have compared one-time broadcast P applications to annual seed-placed P and to various combinations of broadcast and seed-placed P over a 5-year period (**Figure 4**). At low P rates, seed placement appeared to have a slight advantage over broadcast application; however, at optimum rates, broadcast application produced higher yields over the 5-year period even though the initial soil test P level was very low.

Highest yields occurred where an initial heavy broadcast P application elevated soil test levels followed by small annual rates applied with the seed. These data suggest that regardless of placement method(s), it is important to maintain an optimum soil test level to experience the full yield potential of the system.

Similar effects are being measured in an ongoing Colorado study on no-till winter wheat (**Figure 5**). Cumulative response to seed-placed P leveled off at about 100 lb P_2O_5/A and produced a total response of 14 bu/A. The broadcast treatments continued to increase yield to rates exceeding 200 lb P_2O_5/A and produced a total response of about 28 bu/A, twice that of the seed-placed treatments. Like the Saskatchewan study, there was a decided advantage to increasing soil test levels quickly. These studies and others indicate that a soil testing at its optimum level will often have a higher yield potential than one testing low, even when P fertilizer is applied to the low soil.

Summary

Many of the differences in P recommendations attributed to "philosophical" positions appear to be due to the assumptions made about the situation of the individual grower. Small grain profitability could be increased through site specific P recommendations that replace general assumptions with specific soil and grower data and that consider both long-term and short-term effects. ■

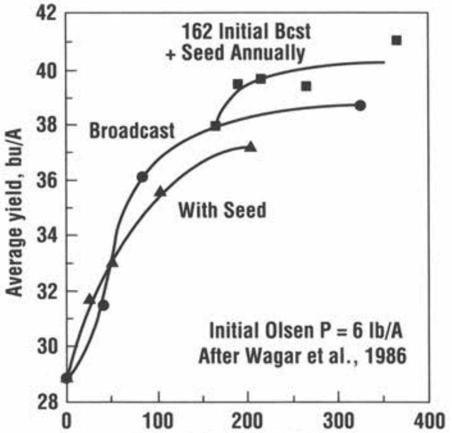

Figure 4. Spring wheat response to P in Saskatoon, 5-year average.

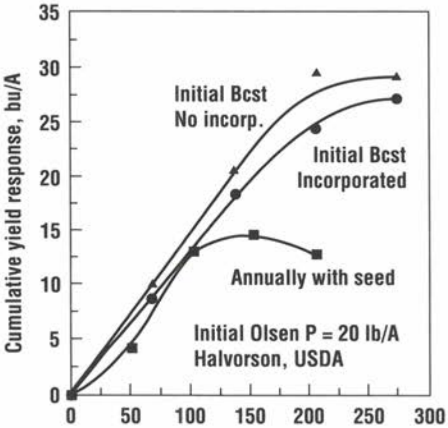

Figure 5. Cumulative winter wheat response to P at Peetz, CO, 3-year totals.

Suspension Fertilizer Placement for Conservation Tillage Grain Sorghum

By Daniel W. Sweeney

Research has shown that fertilizer placement can affect yield in reduced tillage systems. Conservation tillage grain sorghum yields on soils testing low in phosphorus (P) and potassium (K) in Kansas were increased more by knifed applications of nitrogen (N)-P-K suspensions than by broadcast or dribble applications of the same formulations.

SOIL CONSERVATION concerns have been a major factor in growth of conservation tillage systems in the United States. Tillage systems have been shown to affect crops and soil physical, microbial, and chemical conditions. However, the effects of tillage systems on crop yields have often been variable. Research has shown that fertilizer placement can affect yields in reduced tillage systems or when soil test levels are low.

Generally, surface or subsurface banding of fertilizers has often resulted in greater nutrient use efficiency than broadcast applications. Research has also suggested that for improved use efficiency, N and P may need to be placed together in the soil rather than applied separately. The objectives of this study were to assess the effects of broadcast, dribble, and knifed placement methods of N-P-K suspensions (without or without split N applications) on plant growth, yield, and grain nutrient content of grain sorghum in reduced-, ridge-, and no-tillage systems.

Soils

The experiment was conducted at two sites on the Southeast Kansas Branch Experiment Station of Kansas State University. The soil at Site 1 was low in available P and K with a relatively high soil organic matter content. Soil at Site 2 was medium in available P and K but had lower soil organic matter. Soil type at both sites was a Parsons silt loam, a typical claypan soil of the area. Site 1 was native grass prior to fall 1983. Site 2 had been in long-term cultivation.

Tillage and Fertilization Systems

Three conservation tillage systems were used; (1) reduced tillage–disc and field cultivate; (2) ridge tillage; and (3) no-tillage. Fertilizer treatments included combinations of placement methods and split N application, in addition to a no-fertilizer control. Preplant fertilizer application methods were broadcast, dribble (surface band), and knife. Dribble and knife spacing was 30 inches, and knife depth was 4 inches. Nitrogen applications were all N preplant and split N (50 percent of N preplant and 50 percent applied at the 9-leaf stage). Preplant N plus all P and K was applied as a suspension. Later N applications involved use of a urea-ammonium nitrate (UAN) solution. Fertilization rates were 150-100-150 (lb/A of N-P_2O_5-K_2O) at Site 1 and 150-50-100 at Site 2.

Planter problems resulted in poor stands on the ridge tillage and no-tillage systems at Site 2 in the second year of the study, and data were collected only from the reduced-tillage systems.

Yields

Yield was not affected by tillage system at Site 1 in either year. Fertilizer applications increased two-year average yields by more than 16 bu/A regardless of placement

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Table 1. Grain sorghum yield responses to tillage and fertilizer application methods (Site 1) two-year average.

Fertilizer Application Methods	Grain Sorghum Yield, bu/A			
	Tillage			Application Method, Means
	Reduced	Ridge	No-till	
Check	58	57	53	56
Broadcast	76	74	74	75
Dribble	77	79	74	77
Knife	80	81	91	84

method (**Table 1**). Fertilizer placement method significantly affected yields. Knifing produced higher yields than broadcast or dribble applications. Even though knifing tended to increase yields in all tillage systems, placement was more important in the no-tillage system (**Table 1**). Split N applications did not increase yields; however, in the first year of the study, a knife-split N application tended to result in highest yields (data not shown).

Kernel numbers per head were affected by fertilizer application methods (**Table 2**) and paralleled yield responses. These data suggest that the fertilization practices affected the sorghum plants early in the growing season, because the potential number of kernels per head is determined shortly after growing point differentiation. Kernel weight and plant stand were minimally affected by fertilization or placement method (**Table 2**).

Table 2. Sorghum yield component responses to fertilizer application methods.

Fertilization Method	Kernels per Head	Kernel Weight	Plant Stand
		mg	heads/A
Check	1,310	28.2	50,600
Broadcast	1,560	29.1	49,900
Dribble	1,620	29.2	50,300
Knife	1,700	28.9	53,200

Conservation tillage systems, Site 1.

At Site 2 (medium P-K soil), yield was not affected by tillage, placement method, or split N applications (data not shown). However, fertilization–regardless of placement method–increased yields by more than 12 percent above yields obtained in check treatments.

Grain Nitrogen Content

Application of N-P-K suspensions, regardless of method, resulted in a 5 to 9 percent increase in grain N content in the first year of the study at Site 1.

Grain N concentration tended to be higher with knifed applications compared to broadcast or dribble applications. In the second year, however, little difference in grain N content was measured among the fertilizer schemes at Site 1. This may have been partly due to high rainfall in September during grain-fill, in conjunction with a high soil N mineralization potential suggested by initial nitrate-N and organic matter contents. Lower initial nitrate-N and organic matter content at Site 2 may explain the larger responses of grain N to fertilization. In the first year at Site 2, application of the N-P-K- suspensions increased N content in grain by more than 20 percent above the control. In the second year, fertilization increased grain N content more than 87 percent.

Translated to crude protein, adequate fertilization increased grain protein by as much as 5.5 percentage units, having a tremendous impact on the quality of that grain in animal feed production.

Treatment effects on grain P and K concentrations at both sites were small.

Summary

Grain sorghum yields were increased by application of N-P-K suspensions, regardless of placement method, on both low and medium P-K soils in selected conservation tillage systems. Grain yields on a low P-K soils were improved more by knifing fluid fertilizer formulations than by broadcast or dribble applications. Knifed applications were even more effective in a no-tillage system. Suspension placement methods had little effect on yields at the medium P-K site.

Yield increases resulting from both fertilization and placement were related to increased kernels/head. Fertilization also had significant effects on grain N and crude protein concentrations, substantially affecting grain quality as an animal food. ■

My Son Is A Successful Farmer

Success usually comes to those who are too busy to look for it.

There was a time when we spoke with pride about a prominent member of the community who "is a very successful farmer." By that we meant he produced high yields, followed the best conservation practices, improved his land–and, at the same time, made a good profit, provided a good living for his family, and established a sound heritage in land, buildings and equipment so that his heirs could continue farming.

The successful farmer was usually a highly respected community leader, often more so than the local doctor, lawyer or politician. He could conceive of no better legacy for his children than a farm that could continue its role in providing food and fiber for the world.

Such a farmer recently told me that one of his boys was a surgeon, another a professor, and his daughters had married and moved away–no one to whom to leave his place. "I guess they make a greater contribution and lead a fuller life where they are," he said.

No way! This man is unaware of his own importance. He doesn't know that there are only 2 million farms in the U.S. today where there were over 5 million in 1950. He also was surprised to learn that the average farmer feeds 120 people . . . in 1950 he fed only 27.

There IS no more prestigious or more necessary job than that of feeding this ever-increasing world population. One can still say with even greater pride, "My son is a successful farmer."

J. Fielding Reed

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