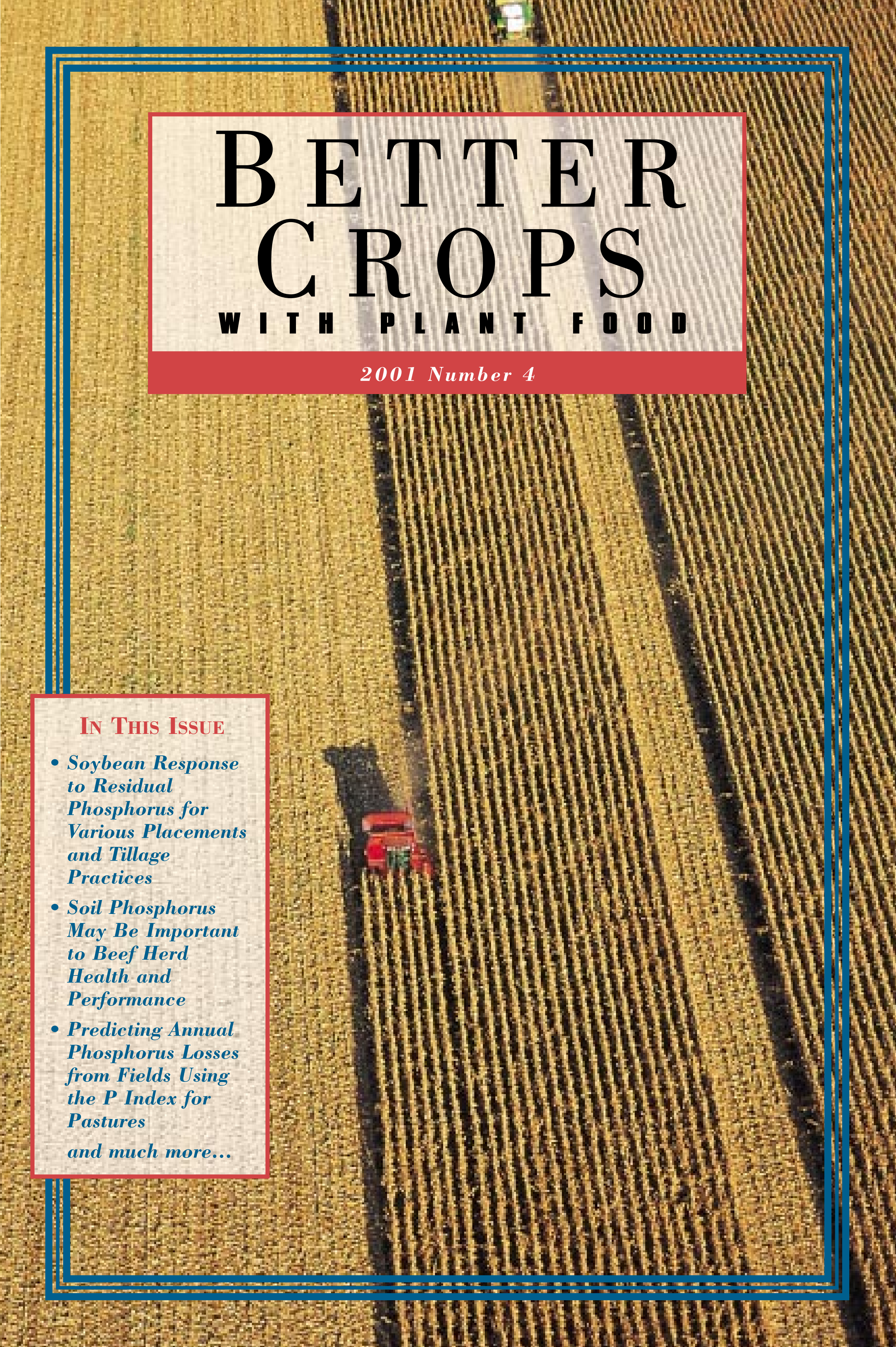

BETTER CROPS
WITH PLANT FOOD

2001 Number 4

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BETTER CROPS
WITH PLANT FOOD

Vol. LXXXV (85) 2001, No. 4

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Both quantity and quality of information now available in electronic form continue to increase at PPI/PPIC/FAR. There are frequent additions and improvements to the sites, which are searchable. Current and previous issues of *Better Crops with Plant Food*, *Better Crops International*, and other publications are available as pdf files.

Each of the regions of North America and globally where the Institute has agronomic research and education programs now has an individualized website accessible from the central site.

Correction to Data in Better Crops #3, 2001

A calculation error occurred in **Table 2** of the article titled "Nutrient Management in Mixed Forage Systems", which appeared on pages 16 and 17 in *Better Crops with Plant Food*, No. 3, 2001. The corrected **Table 2** is shown here. While the values as shown earlier were not correct, the statements and conclusions in the original text remain valid.

TABLE 2. Nutrient balance over the six years and final soil test levels.

Nutrient treatment	Nutrient balance[1], lb/A P_2O_5	Nutrient balance[1], lb/A K_2O	Final soil test[2], lb/A P	Final soil test[2], lb/A K
Control	-217	-543	10	92
N fertilizer	-264	-622	9	88
NPK fertilizer	184	-16	13	116
LD manure	209	84	12	124

[1] Sum of nutrients applied in fertilizer and manure minus those removed in forage harvest.

[2] Modified Morgan soil test level in 2000. Initial soil test levels in 1995 were 15 lb/A for P and 134 lb/A for K.

Soil Phosphorus May Be Important to Beef Herd Health and Performance

By Ryan Lock, Robert Kallenbach, Dale Blevins, Tim Reinbott, Greg Bishop-Hurley, Richard Crawford, Jr., and Matt Massie

Grass tetany is a nutritional disease of ruminants and has been associated with low levels of Mg in forage. This disorder most often affects lactating cows grazing lush, cool-season grass pastures. It is most common during early spring when the grass has a seasonally low Mg concentration and when spring-calving cows have a three-fold greater demand for Mg as a result of milk production.

Although the disease can prove fatal, it rarely progresses to clinical symptoms. More often, a cow suffers from hypomagnesemia, or sub-clinical grass tetany. Hypomagnesemia is a precursor to grass tetany, with symptoms that are difficult to detect, including decreased feed intake, lowered milk production, and loss of body condition. It affects cow performance and health and decreases gains of suckling calves. Thus, it is important that cows consume adequate Mg to ensure the performance of the herd is not compromised.

Typically, producers offer cattle a mineral supplement rich in Mg during the grass tetany season. However, there are problems associated with mineral supplementation. These include the cost, palatability, reliability, and potency of the supplements. Given the fact that supplements can be expensive and do not always work, interest has grown to increase the Mg in cool-season grasses. With this method, a cow would receive her daily requirement of Mg while grazing.

Recent work at the University of Missouri indicates that maintaining soil test P at greater than 30 lb/A can increase the Mg concentration of cool season grasses during spring. Reinbott and Blevins in Missouri published reports in 1991, 1994 and 1997, consistently showing that plants fertilized with P in spring have greater Mg concentrations compared to those grown on low P soils.

Recent research results in Missouri agree with earlier findings that soil phosphorus (P) is important in boosting magnesium (Mg) uptake by tall fescue. Phosphorus fertilization of pastures is a good alternative to Mg supplements for protecting against grass tetany and can help increase calf gains.

Materials and Methods

In a continuation of the work by Reinbott and Blevins, a grazing experiment was conducted at the Southwest Research and

Missouri research indicates that P fertilization of tall fescue pastures can increase forage Mg levels and help protect against grass tetany. Pasture on right in photo, fertilized with P, had a soil test of 30 lb/A Bray P-1. Unfertilized pasture at left had a soil test of only 5 lb/A.

Education Center near Mt. Vernon during the spring of 2000 and 2001. The first objective was to determine if P fertilization of tall fescue would increase the Mg levels in the grass as well as in the animals grazing the grass. Another objective was to compare the Mg status of cows grazing P-fertilized tall fescue to those receiving Mg supplement. The experimental design was a randomized complete block with three treatments and three replications. There were nine pastures, and three cows grazed in each pasture for 56 days beginning February 15, 2000 and again March 6, 2001. The treatments were:

1) Cows grazed tall fescue grown on soil with 34 lb/A available P;
2) Cows grazed tall fescue grown on soil with 6 lb/A available P while supplemented with 12 percent Mg mineral blocks free choice;
3) Cows grazed tall fescue grown on soil with 6 lb/A available P with no supplementation.

For simplicity, the treatments will be referred to as P fertilized, Mg supplement, and control, respectively.

Blood samples were taken from the cows, and forage samples were harvested on the first day of the trial and at 14-day intervals. The Mg concentration of the samples was analyzed. Cows and calves were weighed at these times. Forage availability was kept equal among pastures using electric fencing to control grazing. This method ensured that the Mg status of the animals was a function of forage quality rather than quantity consumed.

Results and Discussion

Forage Mg levels. Preliminary results from this grazing experiment indicate that P fertilization of tall fescue pasture increased the forage Mg levels nearly 20 percent compared to pastures not fertilized with P. This was the case in both years and agrees with previous work suggesting that soil P regulates Mg uptake by tall fescue.

Blood serum Mg levels. Except for March 20, 2001, cows grazing P fertilized pastures and cows receiving Mg supplement showed equal blood serum Mg levels on all sampling dates. On the mentioned date, cows in the P fertilized pastures showed nearly 33 percent less Mg in blood serum than cows receiving Mg supplement. Cold temperatures and snowfall during the three days before this sampling likely reduced the forage intake of these animals because control animals also showed decreased Mg levels at this time, although not as severe. These data suggest that the two groups depending on forage as the only source for Mg could not consume enough dry matter due to the weather conditions at that time. As a result of their decreased forage intake, the cows were unable to consume their daily Mg requirement, and blood serum Mg levels dropped. Cows supplemented with Mg were able to consume the supplement, and their blood serum levels did not drop. As the weather became milder, the cows' Mg status in the P fertilized and control groups returned to previous levels.

The decrease in blood serum Mg of cows grazing P fertilized pasture compared to cows in the control or Mg supplement groups may have also been due to greater milk production coupled with the weather conditions. During cold weather, average daily gains (ADG) of suckling calves were 30 percent higher when their mothers grazed P fertilized tall fescue compared to cows grazing pastures not fertilized with P. This higher rate of gain in calves is perhaps a result of greater milk production by the cows. Since Mg is important for milk production, cows in P fertilized tall fescue may have had more demand for Mg to produce the larger volume of milk needed for the increased calf gains. Therefore, harsh

(continued on page 8)

TABLE 1. Average daily gain of suckling calves for 56 days during the spring seasons of 2000 and 2001.

	Mother cow management		Suckling
Treatment	Pasture Bray P-1, lb/A	Mg supplement	calf ADG, lb
P fertilized	34	Yes	2.44
Mg supplement	6	Yes	2.23
Control	6	No	2.16
LSD (0.05)			0.18

OKLAHOMA

The Magruder Plots – Long-Term Wheat Fertility Research

By R.W. Mullen, K.W. Freeman, G.V. Johnson, and W.R. Raun

In 1891, A.C. Magruder established a continuous winter wheat fertility study at Oklahoma State University that remains ongoing today. The experiment was initially established to evaluate the effect of manure application on wheat yield and determine how long the soil could sustain continuous wheat production. In 1930, treatments evaluating inorganic sources of N, P and K were added. The data set collected over the last 110 years has been a valuable source of information for long-term monoculture wheat fertility and sustainable agriculture.

> This 110-year-old wheat fertility study is a convincing example of the importance of recognizing a soil's nutrient supplying capability in nutrient management. Phosphorus (P) was the first limiting nutrient, then nitrogen (N), and finally potassium (K).

During the early decades of the trial, manure application resulted in a marked increase in yield when compared to the unfertilized check plot (**Figure 1**). Even then, the realization that there was not enough manure to cover all of Oklahoma's wheat ground was noted. As the ability to synthesize inorganic fertilizers increased, treatments evaluating inorganic forms of N, P and K were added to the trial. From the time inorganic fertilizers were first added (1929), yields due to these materials have matched or exceeded those of the manure treatment.

Another important aspect of the Magruder Plots is identifying the onset of macronutrient deficiencies. Comparison of the P only and the NP treat-

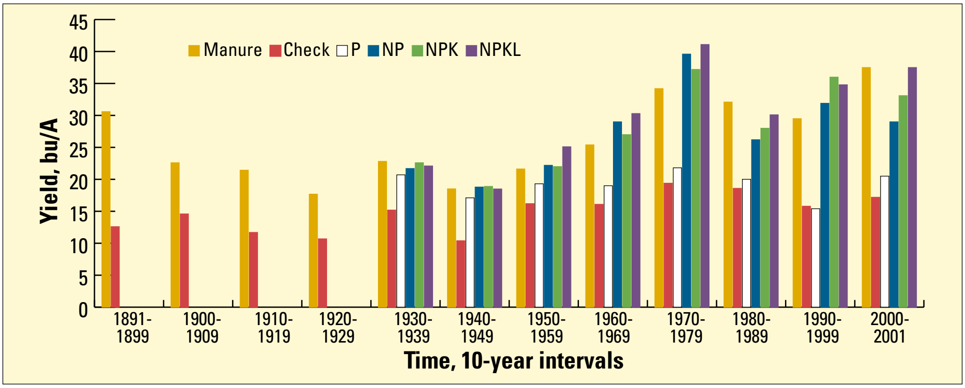


Figure 1. Ten-year average yields for the Magruder Plot treatments, Stillwater, OK, 1890 to 2000.

Manure:	1891-1967, applied at a rate of 120 lb N/A every four years; 1968-present, applied at a rate of 240 lb N/A every four years
Check:	no soil amendments added
P:	1930-1967, P applied as ordinary superphosphate at a rate of 30 lb P_2O_5; 1968-present, applied as triple superphosphate
NP:	1930-1945, N applied as sodium nitrate at a rate of 33 lb N/A; 1946-1967, N applied as ammonium nitrate at a rate of 33 lb N/A; 1968-present, N applied as ammonium nitrate at a rate of 60 lb N/A; P application same as P only treatment
NPK:	N and P treatment same as NP treatment; 1930-present, K applied as potassium chloride at a rate of 30 lb K_2O/A
NPKL:	N, P and K applied the same as NPK treatment; lime (L) applied when soil pH < 5.5

Dr. Bill Webb, Dr. Robert Westerman, and Dr. Billy Tucker (left to right) each served as Manager of the Magruder Plots in past years. Dr. W.R. Raun has handled the responsibility since 1992.

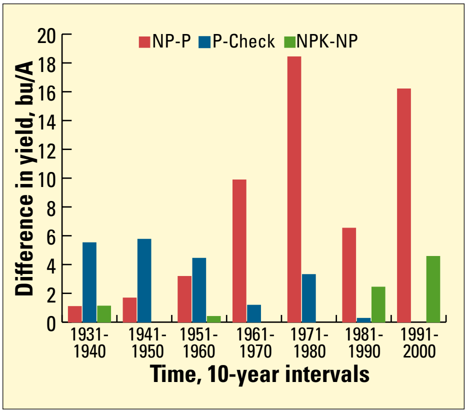


Figure 2. Differences among selected treatments of the Magruder Plots, 1930-2000.

NP-P:	difference in winter wheat yield between NP treatment and P only treatment
P-Check:	difference in winter wheat yield between P only treatment and check
NPK-NP:	difference in winter wheat yield between NPK treatment and NP treatment

ments shows that a considerable difference in yield due to N fertilization was not noted until the 1960s (**Figure 2**). Thus, early in the study, N in rainfall and that mineralized from soil organic matter were sufficient to meet plant needs at these dryland yield levels. A response to applied K was not observed until the 1980s when the yield of the NPK fertilized plots minus that of the NP fertilized plots began to show a difference (**Figure 2**). This coincides with the disappearance of a P response in the P only treatment resulting primarily from the development of N deficiency. However, K was likely a contributing factor since it was also becoming yield limiting. It is interesting to note that when N, P, K, and lime are adequately supplied, there has been little if any benefit from the addition of secondary and micronutrients supplied by the manure treatment.

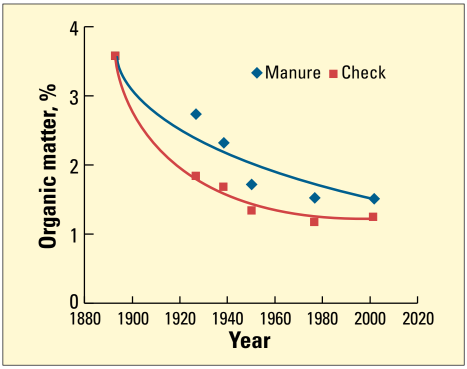


Figure 3. Change in soil organic matter over the last 100 years of the Magruder Plots.

Soil N has decreased notably over the last 100 years, as has the soil organic matter level. In 1893, N and organic matter in the surface soil were 0.16 and 3.58 percent, respectively. After 108 years of monoculture, winter wheat under conventional tillage, soil N and organic matter levels have dropped below 0.06 and 1.50 percent, respectively (**Figures 3** and **4**). The decrease is most notable in the 0 N treatments, resulting from depletion of native N for crop needs. Soil P

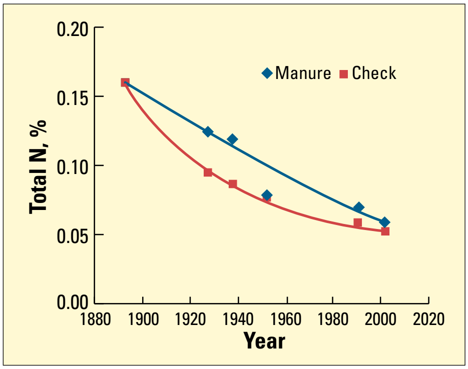


Figure 4. Change in total soil N over the last 100 years of the Magruder Plots.

and K levels have changed considerably over the last 34 years (**Table 1**). Soil test P has decreased in the check, and P levels of the P only treatment are higher than other treatments because N has been limiting, thus reducing yields and P removal.

The data collected from 110 years of monoculture winter wheat on the Magruder Plots have been invaluable. Identifying that in the 1980s soil K was depleted to levels where yield was adversely affected emphasizes the need for soil testing and proper nutrient management. The lack of a considerable response to inorganic N fertilization prior to the 1960s also illustrates that the original source of N in the soil is organic matter. Its contribution of N via mineralization was and continues to be quite significant. On these prairie soils, first tilled in 1892 and in continuous winter wheat since, it took 70 and 90 years to observe N and K responses, respectively.

TABLE 1. Soil P and K levels measured in 1967 and 1997.

Treatment	P	K
	parts per million (ppm)	
	1967[1]	
Check	17.7	316
Manure	27.3	371
P only	50.6	259
NP	35.2	311
NPK	37.5	383
NPKL	30.6	350
	1997[1]	
Check	6.7	231
Manure	41.3	230
P only	55.7	219
NP	46.3	257
NPK	43.2	282
NPKL	38.3	262

[1] In 1967, Bray-Kurtz P-1 for P and ammonium acetate for K; in 1997, both P and K by Mehlich 3.

The authors are researchers at Oklahoma State University, Stillwater.

Beef Herd Health...

(continued from page 5)

weather conditions and a greater demand for Mg may be the cause for the decrease in blood serum Mg observed on March 20, 2001.

Calf performance. Calves had higher rates of gain in both years when their mothers grazed tall fescue fertilized with P (**Table 1**). We thought that milk quality might have been affected by P fertilization. However, when milk samples were analyzed for protein, no differences were found among treatments. Therefore, it seems that the volume of milk produced may have been greater for the P fertilized group compared to the Mg supplement and control animals. As a result, the calves grew faster. If forage availability is greater, cows can produce more milk for their calves. However, we attempted to keep the amount of available forage equal among pastures. Therefore, the greater milk production may have been the result of increased forage quality, although we do not have those data at this time.

Summary

These results agree with previous research indicating the importance of soil P in increasing Mg uptake by tall fescue. Fertilizing pastures with P compares favorably to use of Mg supplements to protect against grass tetany. Further, P fertilization provides additional benefits to cattlemen, including greater calf gains.

Mr. Lock is Graduate Research Assistant, Dr. Kallenbach is Assistant Professor and Extension Forage Crops Specialist, Dr. Blevins is Professor, Mr. Reinbott is Research Associate, and Dr. Bishop-Hurley is Post-Doctoral Fellow, all with Department of Agronomy, University of Missouri, Columbia. Dr. Crawford is Research Assistant Professor and Mr. Massie is Senior Research Specialist, both at Southwest Missouri Research and Education Center, Mt. Vernon.

Onion Response to Phosphorus Placement as Affected by Fumigation

By Brad Brown

Unrestricted early season growth is essential for maximizing onion yields and financial returns. The fumigant Metam Sodium (Vapam®) is commonly used as a non-selective biocide for controlling soil borne diseases, insects, nematodes, and weeds for Idaho's Treasure Valley onions. But it can stunt early season growth, especially in high lime soils. The stunting is commonly attributed to loss of beneficial soil fungi called mycorrhizae that help onions access certain immobile soil nutrients such as P.

Mycorrhizal filaments extend from infected roots and essentially serve as root extensions, allowing the onions to explore greater soil volumes. Onions in high lime soils are particularly susceptible to stunting with Vapam® because available soil P is reduced with lime, and mycorrhizae in the fumigated soil are not available to compensate.

> Crops such as onions which depend on mycorrhizae fungi are especially vulnerable to marginal phosphorus (P) conditions in fumigated soils. Experience in the Treasure Valley of Idaho has shown that fumigation of high lime soils can stunt early season onion growth, but P can fully compensate in some cases. Our research showed that broadcast fertilizer P prior to bedding was more effective for supporting early season growth than P banded below and to the side of planted onion seed.

Previous research by the University of Idaho indicated that fall broadcast P reduced or altogether prevented onion stunting in high lime soils fall fumigated with Vapam®. The P requirements of onions were clearly increased when fumigant was used. Broadcast P fertilizers followed by fall bedding is a common practice for this production area.

Banding P for onions has been more effective than broadcasting P in the Midwest, but not always in other onion production regions. Such evaluations had not been conducted in the Treasure Valley. Our research objective was to further evaluate the stunting effects of Vapam® in relation to applied P, to compare broadcast vs. banded P for the area's production system, and to determine whether fumigation affected soil P availability for subsequent wheat crops.

The study was conducted for three years at the University of Idaho Parma Research and Extension Center on a Nyssaton silt loam soil with low to moderate available P [6.8 to 8.2 parts per million (ppm) sodium bicarbonate P] and appreciable free lime (11 to 12 percent). Phosphorus rates (0 or 58 lb P_2O_5/A) as triple superphosphate were either fall broadcast or fall banded in bed centers. All P treatments were evaluated with and without Vapam® (33 percent active ingredient) injected at 35 gal/A after beds were formed in the fall. The treatments were evaluated with six replications. Onions followed a previous wheat crop.

Yellow Sweet Spanish onion double rows (4 in. apart) were planted on the 22-in. beds in early spring to straddle the banded P. Nitrogen (N) was sidedressed as urea prior to bulbing according to University of Idaho fertilizer guide recommendations. The onions were furrow-irrigated as needed. Weeds and thrips were controlled with labeled pesticides.

Fall fumigation consistently stunted early season onion growth (June dry weight) if no P was fall applied or if the P was fall banded (**Figure 1**). Broadcast P in two of three years was the only P application that fully compensated for the fumigant-induced stunting of early season growth. Where Vapam® was utilized, banded P was clearly less effective than broadcast P.

The importance of mycorrhizae in the stunting of onions could not be determined in this study. Whereas the stunting effects of fumigation in one year were associated with greatly reduced mycorrhizal colonization, mycorrhizal colonization was uniformly low in other years and not influenced by fumigant, although stunting of the onions was just as severe.

Fumigation did not affect the uptake of potassium (K), calcium (Ca), magnesium (Mg), and sulfur (S) in any year. But it did reduce the uptake of zinc (Zn), manganese (Mn), iron (Fe), and copper (Cu) in 1999, and the concentrations and uptake averaged lower in 2000. The differences were not statistically significant (data not shown). Fumigant-induced micronutrient shortages, therefore, may contribute to onion stunting in some years in the Treasure Valley.

The uptake of P by onions in June was not affected by fall-applied P, unless the soil had been fumigated. When fumigated, June P uptake and tissue P concentrations generally increased with added P, especially broadcast P. The results confirm that early season onion requirements for fertilizer P are higher for fumigated soils.

Onion stunting in the foreground resulted with fall fumigation without P. Onions in the background were non-fumigated, with P. At far right, onions were non-fumigated, without P.

Onion yields were limited by P deficiency in only one year without fumigation, but were limited in two of three years with fumigation.

Fumigation consistently delayed maturity regardless of fall-applied P, ultimately reducing bulb size and yield at harvest. Among the fumigated treatments, yield of small bulbs usually tended to be greater with fumigation and banded P, (**Figure 2**) whereas yield of large bulbs or colossals was greater with

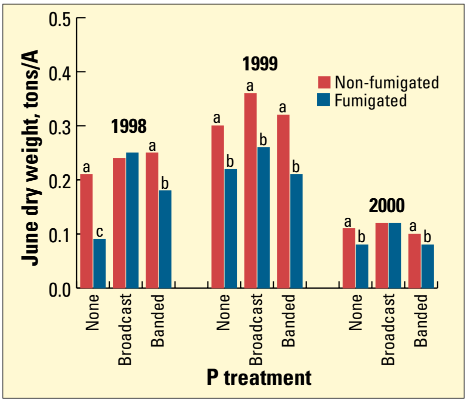


Figure 1. Early season onion growth as affected by P treatment and year. Parma, 1998-00. Different letter denotes a statistical difference between non-fumigated and fumigated treatments at $p < 0.05$ within a given year.

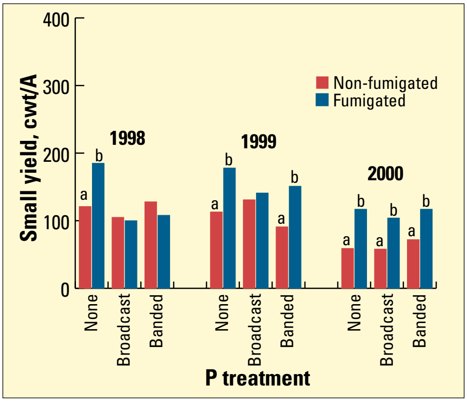


Figure 2. Small onion yield as affected by P treatment. Parma, 1998-00. Different letter denotes a statistical difference between non-fumigated and fumigated treatments at $p < 0.05$ within a given year.

fumigation and broadcast P (**Figure 3**). But fall-applied P fully compensated for the effects of fumigation on bulb size and yield in two of three years if P was broadcast and one of the three years if it was banded. Additional available P was required for fumigated soil to match yields from soils not fumigated. Whereas onion yield did not differ for broadcast and banded P in two years, yield was lower with banding in one year.

The effects of fumigation on subsequent crops have not been widely reported. Winter wheat was fall planted after the onions to measure residual effects from the previous year P fertilizer and fumigation treatments. The adverse effects of fumigation on available soil P extended into the following wheat crop in both of the seasons for which data are available. Either P uptake by wheat at heading or grain yield at maturity was reduced the year following onions grown on fumigated soils. However, wheat grain yield and P uptake were not affected by fumigation the previous year if P had been applied to the onions.

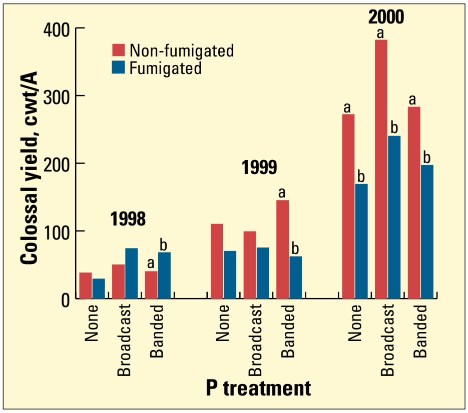


Figure 3. Colossal onion yield as affected by P treatment and year. Parma, 1998-00. Different letter denotes a statistical difference between non-fumigated and fumigated treatments at $p < 0.05$ within a given year.

Summary

Fumigation-induced stunting of onions prior to bulbing was striking and consistent each year in this high lime soil, and fall-applied P could not fully compensate for the effect in all years. Other factors appear to be involved which this study was not designed to evaluate. Banded P with soil-injected Vapam® was less effective than broadcast P. There are compelling pest control reasons to fumigate onion production fields in the Treasure Valley, but adequate levels of P, and possibly other nutrients, are essential to avoid reduced yields of both onions and subsequent wheat in high lime soils.

The author (e-mail: bradb@uidaho.edu.) is an Extension Soil and Crop Management Specialist at the University of Idaho, Parma Research and Extension Center, 29603 U of I Lane, Parma, Idaho 83660. Phone (208) 722-6701 ext. 216; fax (208) 722-6708.

This research was supported by the Idaho-Eastern Oregon Onion Growers Association.

InfoAg 2001 Rates High Marks from Participants

The fifth in the series of Information Agriculture Conferences, InfoAg 2001, took place in August at Indianapolis, Indiana. More than 400 attended the event, which was organized by PPI/PPIC/FAR in cooperation with other partners, sponsors and supporters. Program partners for InfoAg 2001 included *CyberDealer* and *CropLife* magazines (Meister Publishing) and *Indiana Prairie Farmer/Prairie Farmer* magazines (Farm Progress Companies).

For more information, call (605) 692-6280 or fax (605) 697-7149. Proceedings papers for InfoAg 2001 are posted on the website at www.ppi-far.org/infoag.

MINNESOTA

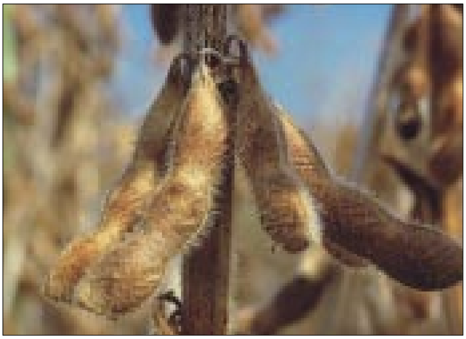
Soybean Response to Residual Phosphorus for Various Placements and Tillage Practices

By G.W. Randall, J.A. Vetsch, and T.S. Murrell

Row-crop agriculture in the Mississippi River Basin is under intense pressure to reduce sediment and nutrient losses by practicing less tillage and more precise application and placement of nutrients, especially nitrogen (N) and P. By keeping more crop residue at the soil surface, reduced tillage systems can limit sediment losses. The tillage system keeping the most residue at the surface is no-till. However, in the northern portions of the Corn Belt, corn yields are generally lower in no-till systems because of wetter and cooler soils at the time of planting. Other tillage systems are being investigated to find solutions offering adequate surface cover while providing good growing conditions. Currently used conservation tillage alternatives are strip tillage (strip-till) and one-pass secondary tillage. Strip tillage, or zone tillage, disturbs the soil to a depth of 7 to 8 in. and creates a 4 to 6 in. wide by 1 to 2 in. high mound of soil that is free of residue. The tilled area is warmer and drier at planting time. One-pass secondary tillage systems consist of no primary tillage in the fall and either field cultivation or a disking operation in the spring.

Under very low soil test phosphorus (P) levels, significant soybean yield responses to residual P were observed for all placements in a Minnesota study. Banded applications at half the recommended broadcast rate were not sufficient to optimize soybean yields.

In the corn growing areas of Minnesota, soybeans frequently follow corn in crop rotations. The effects of surface residue on temperature and moisture are not considered as important for soybeans, which can be planted later when soils are drier and warmer. Therefore, strip-till is not normally performed for the soybean crop. Instead, where strip-till was used in the previous corn year, most producers revert to no-till for the subsequent soybean crop.



When soil tests are low, substantial soybean yield increases may result from residual P applied either broadcast or in bands the previous year for corn.

Most producers do not apply fertilizer prior to planting soybeans. They generally rely on the residual effects of fertilizer, primarily P and potassium (K), applied for the

TABLE 1. Soybean yields associated with each tillage practice, averaged across years (1998-2000) and similar P management practices.

Tillage	Soybean yield, bu/A High P site	 Low P site
No-till	53.4	41.5
One-pass	55.6	42.5
Strip-till (c); no-till (s)	53.7	43.5
Chisel	56.1	42.1

prior corn crop. Previous research in Minnesota has shown that under conventional tillage, soybeans generally respond best to broadcast applications of P. However, in reduced tillage systems, less soil disturbance limits the opportunity for incorporation of broadcast P fertilizers. Therefore, banded applications, as with starters or deep banding, serve as viable alternatives to broadcast applications and are commonly used for corn. Application of P below the soil as bands serves two purposes: 1) It places P in the soil volume where it is easily accessible by roots and 2) concentrated zones of P can decrease fixation, making P more readily available for plant uptake. For these reasons, the University of Minnesota recommends that rates of banded P be reduced to half the recommended broadcast rate at Bray P-1 greater than 5 parts per million (ppm). We tested this recommendation to understand how P management for corn affected soybean response in the subsequent growing season.

A study was begun in the fall of 1996 on a tile-drained Nicollet-Webster clay loam soil complex located at the Southern Research and Outreach Center, Waseca, Minnesota. The study utilized a corn-soybean rotation and several P and tillage management practices. Two adjacent sites were used. The high P site had been previously maintained at approximately 19 ppm Bray P-1 with periodic P fertilizer applications while in a corn-corn-corn-soybean rotation. The low P site had previously been in a continuous corn rotation and received no P for 15 years to mine soil P to very low levels (3 to 4 ppm Bray P-1). Tillage practices were no-till for both corn and soybean years, one pass of a field cultivator (for corn) or a disk (for soybeans) in the spring (one-pass), fall strip-till for corn [strip till (c)], followed by no-till for soybeans [no-till (s)], and chisel tillage (chisel) utilizing a chisel in the fall plus a field cultivator in the spring for both crops.

Phosphorus was applied only for corn. Phosphorus application methods for all tillage practices in the corn year included a check (no P) and a band application in the seed furrow at planting (starter). Broadcast applications with subsequent incorporation were made for the one-pass and chisel systems. The starter and broadcast P rates applied for corn every other year were 40 and 80 lb P_2O_5/A, respectively, for the high testing site and 50 and 100 lb P_2O_5/A, respectively, for the low testing site. For the strip-till and one-pass tillage practices, deep band P applications were made in the fall, prior to the corn crop, at rates of 40 and 50 lb P_2O_5/A for the high and low testing sites, respectively. In the strip-till system, two types of band positions were tested. In the fixed band treatment [deep band (f)], the band was placed about 5 in. deep, with the strip tiller in approximately the same place prior to each corn year. In the random band treatment [deep band (r)], the placements were offset by 8 in. between the two years when they were applied. In the one-pass system, the fall band treatment was placed about 5 in. deep in a band that ran at about

TABLE 2. Three-year average soybean yield responses (1998-2000) to residual P from starter fertilizer applied for corn the previous year on sites testing high and low in soil P.

Tillage for		P application	P_2O_5 applied, lb/A		Grain yield, bu/A	
Corn	Soybean	method	High P	Low P	High P	Low P
No-till	No-till	None	0	0	53.2	36.7
		Starter	40	50	53.5	46.4
One-pass	One-pass	None	0	0	55.5	37.6
		Starter	40	50	55.7	47.3
Strip-till	No-till	None	0	0	53.5	38.3
		Starter	40	50	53.2	48.8
Chisel	Chisel	None	0	0	56.0	33.7
		Starter	40	50	56.2	50.4
Average		None	0	0	54.6	36.6
		Starter	40	50	54.7	48.2

a 2° angle to where the corn row was planted. This assured that the fertilizer band was not located continuously under the corn row, but varied from directly under the row to as much as 15 in. from the row.

After each corn year, soybeans (Pioneer 91B64) were planted at a rate of 160,000 seeds/A in 8 in. rows using a drill. No fertilizer was applied to the soybeans to test the residual effects of P applied in the previous corn year.

Tillage Effects

The effects of tillage on soybean yield for both high and low P sites are shown in **Table 1**. At the low P site, there was no significant difference among the various tillage practices, and average yield for the site was 42.4 bu/A. On the high P site, soybean yields were 2 to 3 bu/A higher where either disk (55.6 bu/A) or chisel (56.1 bu/A) tillage had been done compared to no-tillage.

In **Table 1** and the following tables, the high P site exhibited higher overall yields than the low P site. Although a statistical comparison between the two sites is beyond the scope of this study, the higher yields associated with the high P site are suspected to be largely due to better P soil fertility.

Residual Effects of P Applied as a Starter Band

Soybean yield response to residual P applied in starter fertilizer in the previous year for corn are shown in **Table 2**. At the high P site, no response was observed for any tillage practice. At the low P site, significant responses occurred for all tillage systems. Yield increases were 9.7, 9.7, 10.5, and 16.7 bu/A for the no-till, one-pass, no-till following strip-till, and chisel tillage practices, respectively. Corn grain yield responses behaved similarly for each tillage practice. The overall response to starter, averaged across all tillage systems, was 11.6 bu/A.

Testing the Efficiency of Banded P

The effects on soybean yield of reducing banded rates to half the recommended broadcast rates are shown in **Table 3**. At the high P site, there was no yield difference from residual P with either broadcast or banded P applications. At the low P site, soybean yields from the broadcast P treatments were significantly greater (3.7 to 4.9 bu/A) than yields from the starter P treatments. These data suggest that band applications of P applied to corn at a half-rate to low testing soils do not supply sufficient residual P to optimize soybean yields in the following year compared to broadcast applications of P at the fully recommended rate.

Evaluating Residual Effects of Different Band Placements of P

Soybean yield responses to residual P from various band placements in the previous corn year are shown in **Table 4**. At both the high and low P sites, no significant yield difference was detected between the residual effects of P applied as starter or in deep bands in the one-pass tillage system. In no-till following the strip-till system, significantly lower soybean yields were produced

TABLE 3. Three-year average soybean yield responses (1998-2000) to residual P from starter and broadcast P applied to corn for one-pass and chisel cultivation tillage practices on sites testing high and low in soil P.

Tillage for		P application	P_2O_5 applied, lb/A		Grain yield, bu/A	
Corn	Soybean	method	High P	Low P	High P	Low P
One-pass	One-pass	None	0	0	55.5	37.6
		Starter	40	50	55.7	47.3
		Spring broadcast	80	100	54.8	52.2
Chisel	Chisel	None	0	0	56.0	33.7
		Starter	40	50	56.2	50.4
		Fall broadcast	80	100	56.4	54.1
Average		None	0	0	55.8	35.7
		Starter	40	50	56.0	48.9
		Broadcast	80	100	55.6	53.2

from residual P when fall band locations were offset from year to year [fall band (r)]. No yield reductions were detected when P was placed in the same position during each strip tillage operation [fall band (f)].

Summary

Soil test P level is an important factor for understanding soybean yield responses to residual P from various P placements and tillage practices. Placement is less of a consideration when soil tests are high. However, when soil tests are low, substantial yield increases may be seen from residual P applied either broadcast or in bands the previous year for corn. Reducing banded rates to half the rate recommended for broadcast applications did not optimize yields and overestimated the efficiency of P banding in this study.

TABLE 4. Three-year average soybean yield responses (1998-2000) to residual P from starter and deep band P applied to corn for one-pass and no-till following strip-till practices on sites testing high and low in soil P.

Tillage for		P application	P_2O_5 applied, lb/A		Grain yield, bu/A	
Corn	Soybean	method	High P	Low P	High P	Low P
One-pass	One-pass	None	0	0	55.5	37.6
		Starter	40	50	55.7	47.3
		Fall band	40	50	54.8	47.6
Strip-till	No-till	None	0	0	53.5	38.3
		Starter	40	50	53.2	48.8
		Fall band (f)	40	50	54.2	48.1
		Fall band (r)	40	50	54.6	43.9

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Research Notes

Iowa: No-Tillage Soybean Response to Banded and Broadcast and Direct and Residual Fertilizer Phosphorus and Potassium Applications

Researchers evaluated the response of soybeans to fertilizer phosphorus (P) or potassium (K) placement and rates, along with residual and direct-placed fertilization, over a two-year period (1995-1996). Studies (two P and two K tests) were conducted on farmer fields with 10-year histories of no-till. In addition, a P experiment was established on one of Iowa State University's research farms. Treatments on farmer fields included two rates of P, 0 and 40 lb P_2O_5/A, or two rates of K, 0 and 55 lb K_2O/A, placement of fertilizer (surface broadcast or subsurface band 2 in. beside and 2 in. below the seed), and time of fertilizer application. Treatments on the research farms were similar except the P fertilizer rates were 0, 40, 80, and 160 lb P_2O_5/A.

Placement effects were variable for leaf P or K concentration, and grain yields for broadcast P and K were as good as or better than banded applications. Researchers pointed out that there might be an advantage to applying P directly to the soybean crop, at least when soil test levels are optimum or lower.

Source: Buah, Samuel S.J., Thomas A. Polito, and Randy Killorn. 2000. Agron J. 92: 657-662.

Predicting Annual Phosphorus Losses from Fields Using the Phosphorus Index for Pastures

By P.B. DeLaune and P.A. Moore, Jr.

Non-point P runoff from pastures receiving animal manure applications is believed to play an important role in accelerated algal growth in nearby water bodies. Therefore, concerns have arisen over proper P management. According to the Environmental Protection Agency (EPA) Concentrated Animal Feeding Operations (CAFO) draft regulations, manure application rates for P may be determined using soil test P levels, threshold soil test P levels, or a P Index (PI).

The original PI was implemented by the Natural Resources Conservation Service (NRCS) as a risk assessment tool for use across the country. The PI combines the effects of both P sources and P transport factors in determining the risk of P runoff. Several states are now modifying the original PI in order to better assess the risk of P loss in local regions. Some states are attempting to determine threshold soil test P levels above which animal manures or commercial P fertilizer may not be applied due to increased risk of P runoff. The objective of this study was to develop a PI for pastures in the Ozark Highlands.

Runoff studies showed that soil test phosphorus (P) is poorly correlated to soluble reactive P (SRP) runoff concentrations after P applications of manure and commercial fertilizer have been made. Soluble P in the nutrient source was shown to be the most important factor affecting P loss.

Calibration Using Small Plots

Seventy-two small runoff plots (5 ft. x 20 ft., 5 percent slope) were constructed on a Captina silt loam at the University of Arkansas Agricultural Research Station in Fayetteville. Tall fescue was established on each of the runoff plots. Six runoff studies were conducted to determine the effects of the following treatments on P runoff:

1. Soil test P (six levels of soil test P)
2. Soluble P in poultry litter (four levels of soluble P)
3. P in diet [normal diet, phytase, high available P (HAP) corn, and phytase + HAP]
4. Fertilizer type [triple superphosphate (TSP; 0-46-0) vs. poultry litter]
5. Poultry litter application rate
6. Timing (first runoff event 1, 7, 21, or 49 days after fertilization)

Rainfall simulators were used to provide a 2 in./hr. storm event sufficient in length to cause 30 minutes of continuous runoff. Runoff water was collected and analyzed for SRP.

In order to obtain a wide range of soil test P levels, TSP was incorporated into 24 plots during construction at rates equivalent to 0, 344, 687, 1,374, 2,061, and 2,748 lb P_2O_5/A. Although these rates are high for pasture and hay producers without access to manure, the soil test P levels resulting from these rates are realistic and typically found in pastures which have received annual poultry litter applications for many years.

Small Plot Research Results

Study 1: Average soil test P levels (Mehlich 3, 0- to 6-in.) were 233, 318, 439, 609, 737, and 946 lb/A following additions of 0, 344, 687, 1,374, 2,061, and 2,748 lb P_2O_5/A. The first rainfall simulation was conducted prior to any manure applications. Results show that runoff P concentrations are well correlated to soil test P (**Figure 1a**). Rainfall was applied to the same plots one week later, and a similar relationship was found (data not shown). Prior to the third rainfall simulation, poultry litter was applied at rates equivalent to 2.5 tons/A. No relationship was found between soil test P and SRP runoff concentrations after manure application (**Figure 1b**). However, a good relationship was found between SRP runoff concentrations and SRP concentrations in the litter applied (**Figure 1c**). These data provide evidence that P solubility of the litter is much more important in regulating P runoff than soil test P of recently manured fields.

Study 2: The effect of SRP in litter was determined using various rates of aluminum sulfate (alum). Mean SRP runoff concentrations were 0.88, 13.4, 15.1, and 26.0 parts per million (ppm) P for litter treated with 20 percent alum, 10 percent alum, 5 percent alum, and untreated litter, respectively (data not shown). Previous research (Self-Davis and Moore, 1998, *Better Crops*, Vol. 82, No. 4) has shown that alum additions to poultry litter reduced SRP runoff concentrations. Increasing litter alum rates resulted in reductions in SRP concentration in runoff.

Study 3: Diet manipulated litter resulted in the highest SRP runoff concentrations among all of the manure treatments. Total P application rates are listed in **Table 1**. Runoff P concentrations may be expected to be highest from plots receiving litter from the normal diet due to a high total P content. However, SRP runoff concentrations were actually highest from the phytase and HAP corn diets (**Table 1**). This is because SRP concentrations in the manure were highest in the phytase and HAP corn diets.

These results show that SRP

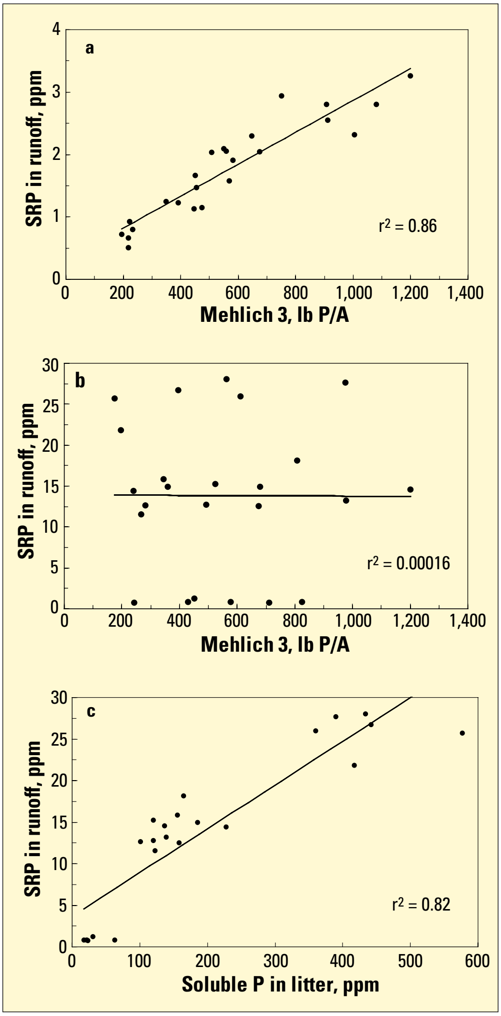

Figure 1. Effect of soil P on SRP runoff concentrations with (a) no manure; (b) manure application; and (c) effect of litter P solubility on SRP runoff, based on small plot research using simulated rainfall.

TABLE 1. Phosphorus application rates and P runoff concentrations of different poultry diets.

Diet	Total P applied, lb/A	SRP applied, lb/A	SRP in runoff, ppm
Normal	111.0	8.0	39.1
HAP	83.9	13.7	65.9
Phytase	66.5	17.9	84.6
HAP + Phytase	56.3	4.5	36.5

application rates are more important in affecting P runoff from pastures than total P application rates. Previous research studies have also shown that P runoff from perennial grass pastures is predominantly of the soluble form because there is little erosion and minor loss of sediment-bound P.

Study 4: Mean runoff SRP concentrations were 13.4, 26.0, and 103 ppm P for plots which received alum-treated poultry litter, normal poultry litter, and TSP at 160 lb P_2O_5/A (data not shown). This is expected since the P solubility of commercial fertilizer is much higher than that of animal manures. As much as 94 percent of TSP is SRP whereas only 2 to 4 percent of the total P in normal poultry litter is SRP.

Study 5: Runoff SRP concentrations resulting from three rainfall simulations increased linearly with increasing poultry litter application rates (**Table 2**). Soil test P levels were similar for each of the plots. Mean SRP runoff concentrations for the third rainfall simulation from plots receiving 1 ton/A rates remained higher than that of unfertilized controls, thus showing that soluble P of applied litter is an important factor in regulating P runoff even after three runoff events.

Study 6: Mean runoff SRP concentrations were 3.0, 8.8, 14.3, and 17.6 ppm P for 49, 21, 7, and 1 days until the first runoff event occurred after litter application. If several small, non-runoff storm events occurred before the first runoff event, then P runoff could be greatly reduced. However, data on large fields show that as much as 12 to 18 months may be needed to reduce P runoff concentrations to background levels. Applying poultry litter at times having a low P runoff risk, such as July or August, would also be the worst period to apply with respect to volatile ammonia nitrogen (NH_3-N) loss. Therefore, results from this study were not utilized to develop the P source term of the PI for pastures.

TABLE 2. Runoff P concentrations (ppm) from various poultry litter applications rates.

Litter application rate, tons/A	Rainfall simulation, (Days after litter application) 1 (<1)	2 (7)	3 (14)
0	1.2	0.9	0.9
1	8.8	5.2	4.8
2	16.6	8.9	5.4
3	27.8	14.9	8.2
4	33.0	20.0	8.8

TABLE 3. Phosphorus Index for pastures – interpretation and recommendations.

Risk of P runoff	PI rating	Interpretation/recommendation
Low	< 0.6	N based
Medium	0.6 - 1.2	N based
High	1.2 - 1.8	P based
Very high	> 1.8	No P application

Pasture PI Development

The PI for pastures, based on the template initially proposed by the USDA-NRCS, is a multiplicative matrix that includes P source factors, P transport factors, best management practices (BMPs), and a precipitation factor. The PI for pastures is calculated from the four terms as follows:

PI = (P sources) x (P Transport) x (BMPs) x (Precipitation)

Data from runoff studies discussed above (Studies 1-5) were used to develop weighting coefficients for P source factors

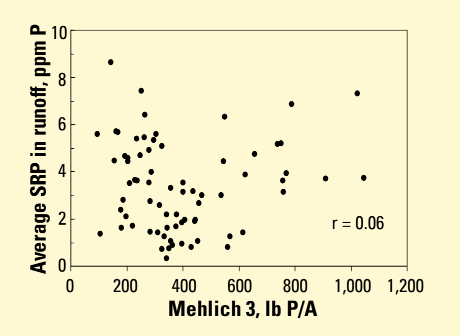

Figure 2. Relationship between Mehlich 3 P and SRP runoff concentrations from rainfall simulations conducted in farmer pastures.

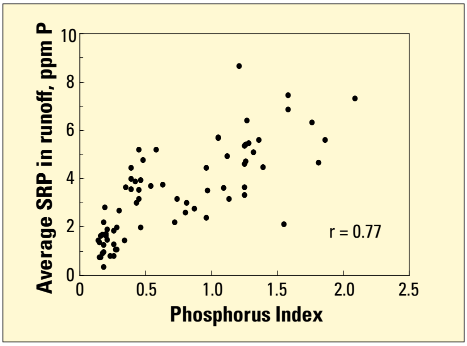

Figure 3. Relationship between the PI and SRP runoff concentrations from rainfall simulations conducted in farmer pastures.

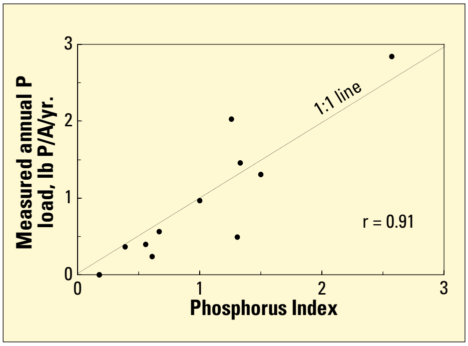

Figure 4. Relationship between measured annual P load from one-acre, pastured watersheds and the PI.

(soil test P and soluble P application rate). Multiple regression analysis showed weighting coefficients to be 0.000666 for soil test P and 0.404 for soluble P application rate.

Transport factors include soil erosion, runoff class, flooding frequency, application method, application timing, and grazing management. Based on the calculated PI, fields are assigned a class of low, medium, high, or very high potential for P movement. Once a high PI rating is achieved, it is recommended that nutrients be applied at rates no higher than current crop P needs. Furthermore, no P application should be made on fields having a very high PI rating (**Table 3**).

Small Plot Validation of the Pasture PI

Validation studies were conducted on six farms of various forage cover and slope in Arkansas and Oklahoma. Twelve small plots were constructed on each farm, and portable rainfall simulators were used to provide a 2.8 in./hr. storm event. Plots were built on various soil test P levels determined from previous intensive soil sampling. Poultry litter was applied based on the PI for pastures to half of the plots and NRCS guidelines (no P application with 0- to 6-in. soil test P > 300 lb/A) to the other half. Litter was applied to provide PI values ranging from low to high. Six runoff events were conducted on each of the 72 plots, three before litter application and three afterwards. The average SRP runoff concentrations from the six runoff events at each farm were poorly correlated to 0- to 6-in. soil test P (**Figure 2**). This trend is similar to that found in runoff studies in the development of the PI. However, a much better correlation was found between SRP runoff concentrations and the PI for pastures (**Figure 3**). These results show that soil test P is a poor predictor of P runoff concentrations once manure is applied. The PI for pastures was a much better predictor of P runoff than soil test P, showing that P applications, as well as transport factors, should be taken into account.

Watershed Validation of the Pasture PI

Although the PI was shown to be a better predictor of P losses, these studies were conducted on small plots under simulated rainfall. Therefore, annual P loads (lb P/A/yr) were measured for two 1-acre watersheds which had received litter applications annually since 1994. Each watershed is hydrologically isolated with earthen berms and equipped with flumes and automated water samplers. Since soluble P application rates were recorded each year, the PI could be calculated. Runoff volume, runoff P concentrations, and runoff P loads were measured each year. The relationship between measured annual P loads and the PI

(continued on page 23)

MANITOBA

Spring Wheat Cultivar Response to Potassium Chloride Fertilization

By Cynthia A. Grant, Debra L. McLaren, and Adrian M. Johnston

Chloride (Cl) is one of the 17 essential nutrients required for plant growth and development. Chloride plays a major role in plant function, including photosynthesis, enzyme activation, nutrient transport, water movement in cells, stomatal activity, accelerated plant development, reduced lodging, and improved disease suppression and tolerance.

Increases in grain yield occurred frequently with potassium chloride (KCl) application, but response patterns for cultivars were not consistent from year to year or location to location.

Chloride is a mobile nutrient in the soil like nitrate (NO_3) and as such can move freely with the soil water. Consequently, soil Cl levels can increase or decrease from year-to-year, depending on the water table and landscape position used to collect soil samples. A soil Cl level less than 30 lb/A in the top 2 ft. of soil is generally used as an indication that insufficient Cl is available for optimizing grain yield of cereals. Levels of 30 to 60 lb/A may provide a crop response, while those above 60 lb/A are unlikely to be responsive.

Research across the Great Plains has identified that there is a strong varietal response of cereal crops to soil Cl levels. To evaluate the effect of soil and fertilizer Cl on annual spring wheat cultivars common to western Canada, a trial was conducted at the Agriculture and Agri-Food Canada Brandon Research Centre between 1996 and 1998. A selection of Canadian and adapted American hard red spring wheat varieties, along with Canada Prairie Spring, Canada Extra Strong, and Canada Western Amber Durum varieties, were grown on low to moderate Cl testing soils. The wheat cultivars were grown with and without 40 lb Cl/A applied as KCl. The KCl was applied as a pre-plant spring band.

Two trial sites were used in each of the three years of the study, one a clay loam texture and the other a fine sandy loam texture. Soil Cl levels were low in all years at the fine sandy loam site and in 1996 and 1998 at the clay loam site (**Tables 1** and **2**). A moderate soil Cl level was recorded for the clay loam site in 1997. Soil potassium (K) levels were determined and found to be lower on the fine sandy loam soil (332 lb K/A in 1996, 288 in 1997, and 192 in 1998), relative to the clay loam (732 lb K/A in 1996, 510 in 1997, and 680 in 1998). Response of cultivars to Cl addition were evaluated for their statistical significance and the ability to return C$1.50 for each C$1.00 invested in fertilizer (fertilizer economics). Using a wheat price of C$4.00/bu and C$0.17/lb for Cl, this worked out to a 2.5 bu/A yield increase.

Few significant differences were observed in the Canadian and U.S. hard red spring wheat cultivars on the sandy loam soil site (**Table 1**). Where significant differences were recorded, addition of Cl did increase grain yields. From a fertilizer economics evaluation, 17 of the 30 cultivar-years (three years x 10 cultivars) showed a positive response to Cl addition, 11 showed no yield difference, and two showed a yield decline of more than 2.5 bu/A (**Table 3**).

The cultivar AC Barrie was the only hard red spring wheat to consistently give an economic response. Other cultivars like Guard showed a significant positive response in 1998, no difference in 1996, and an economic yield loss from Cl addition in 1997. On average, all of the Canadian hard wheat cultivars showed a yield response of more than 2.5 bu/A on this sandy loam soil, while only Pioneer 2375 was responsive amongst the U.S. hard wheat types (**Table 3**).

Significant positive responses were recorded with the Canada Prairie Spring wheat cultivar AC Karma and the Amber Durum cultivars Kyle and Plenty at this fine sandy loam soil site (**Table 1**). While Cl addition resulted in a large positive yield response for AC Karma and Kyle in two years, both cultivars showed a negative economic response in 1997 (**Table 3**). Results were equally variable among years for Glenlea and AC Taber. These results confirm that crop response to Cl is not specific to low soil Cl levels alone, but is also influenced by the cultivar and the growing season. It is important to note that given the low to medium soil test K levels at the sandy loam site, some of the yield responses recorded could be due to the K applied with the Cl in the KCl fertilizer.

While Cl levels at the clay loam site were low to moderate in all years of the study, few significant grain yield responses were recorded (**Table 2**). Considering all classes of wheat in the study, only seven of the 45 cultivar-years (three years x 15 cultivars) showed a significant positive response,

TABLE 1. Effect of cultivar and KCl treatment on grain yield on a fine sandy loam soil in 1996, 1997 and 1998, Brandon, MB.

	Grain yield, bu/A								
	1996			1997			1998		
Cultivar	**-Cl**	**p>f**	**+Cl**	**-Cl**	**p>f**	**+Cl**	**-Cl**	**p>f**	**+Cl**
Canada Western Red Spring									
AC Barrie	27.1	ns	34.6	37.5	ns	44.5	36.3	*	42.0
CDC Teal	35.0	ns	34.3	32.4	ns	37.3	37.6	ns	41.4
AC Cora	28.8	+	33.8	38.8	ns	37.7	32.1	ns	38.6
AC Domain	28.1	ns	33.1	38.8	ns	37.8	35.9	*	44.3
AC Majestic	29.9	*	40.8	38.1	ns	41.6	38.7	ns	39.8
Roblin	27.1	**	32.0	27.3	ns	30.2	31.5	+	33.2
U.S. Hard Red Spring									
Grandin	37.1	ns	31.6	38.2	ns	37.8	32.7	ns	37.5
Pioneer 2375	32.7	ns	39.3	36.8	ns	39.0	41.4	ns	43.3
Marshall	41.8	ns	41.4	37.0	ns	40.0	44.4	ns	45.0
Guard	28.9	ns	28.9	32.2	ns	29.2	37.2	**	43.4
Canada Prairie Spring									
AC Karma	27.4	*	42.3	42.5	ns	37.7	38.3	+	45.0
AC Taber	35.9	ns	29.9	40.1	ns	46.2	44.2	ns	48.3
Canada Western Extra Strong									
Glenlea	29.3	ns	25.4	33.2	ns	38.0	37.4	ns	39.2
Canada Western Amber Durum									
Kyle	25.2	ns	32.6	39.0	ns	35.6	30.0	+	37.1
Plenty	22.5	+	31.5	30.1	**	37.6	36.4	ns	38.6
Soil test Cl (24 in.)		8 lb/A			10 lb/A			8 lb/A	

ns, +, *, ** represent not statistically significant, and significant at $p = 0.10$, 0.05, and 0.01, respectively, using orthogonal contrasts.

TABLE 2. Effect of cultivar and KCl treatment on grain yield on a clay loam soil in 1996, 1997 and 1998, Brandon, MB.

	Grain yield, bu/A								
	1996			1997			1998		
Cultivar	**-Cl**	**p>f**	**+Cl**	**-Cl**	**p>f**	**+Cl**	**-Cl**	**p>f**	**+Cl**
Canada Western Red Spring									
AC Barrie	52.5	ns	51.5	54.7	ns	54.5	45.3	ns	45.8
CDC Teal	56.4	**	51.2	57.3	ns	56.1	51.8	ns	53.9
AC Cora	56.6	ns	56.5	52.6	ns	53.0	44.3	ns	45.9
AC Domain	51.6	ns	52.9	50.8	ns	53.2	53.4	+	52.1
AC Majestic	56.7	ns	59.5	50.2	ns	48.4	50.3	ns	51.9
Roblin	47.6	+	44.0	51.4	ns	48.1	43.2	ns	43.4
U.S. Hard Red Spring									
Grandin	52.6	ns	52.1	60.1	ns	60.5	52.3	ns	51.4
Pioneer 2375	60.3	ns	57.0	59.6	*	66.4	53.4	ns	53.8
Marshall	60.6	*	56.7	61.9	**	67.8	55.0	ns	52.0
Guard	54.4	ns	54.9	57.0	+	62.8	57.0	ns	56.4
Canada Prairie Spring									
AC Karma	57.9	*	66.4	53.8	**	64.0	56.6	+	62.9
AC Taber	60.7	ns	60.3	58.6	+	55.0	60.9	ns	58.7
Canada Western Extra Strong									
Glenlea	57.6	ns	58.8	54.6	ns	59.6	61.8	ns	60.1
Canada Western Amber Durum									
Kyle	61.2	ns	63.9	61.9	*	69.2	51.2	ns	50.1
Plenty	65.2	ns	67.1	68.6	ns	72.5	51.8	ns	57.3
Soil test Cl (24 in.)		8 lb/A			44 lb/A			18 lb/A	

ns, +, *, ** represent not statistically significant, and significant at p = 0.10, 0.05, and 0.01, respectively, using orthogonal contrasts.

while five showed a significant negative response to Cl addition. While AC Barrie showed a strong response to Cl addition at the fine sandy loam location, there was no response on the clay loam soil type. From a fertilizer economics point of view, yield responses were small, with only 12 of the 45 cultivar-years showing a positive response to Cl addition (**Table 3**). There were seven cultivar-years where Cl addition reduced grain yield by more than 2.5 bu/A, while the difference was less than this in the remaining 26 cultivar-years. On average across the study years, grain yield responses of greater than 2.5 bu/A were only recorded with AC Karma and the two durum cultivars. These results would indicate that while the soil Cl levels were low to moderate at this clay loam soil site, response to KCl addition was considerably less than on the fine sandy loam soil location.

Increases in grain yield occurred frequently with KCl application, but the KCl response patterns for cultivars were not consistent from year to year or location to location. Decreases in crop yield with KCl application occurred in some site-year-cultivar combinations. The reason for the yield depression was uncertain. Consistent increases in grain yield with KCl application occurred in the cultivar Karma, which showed positive response to KCl application in five of the six site-years. Due to the inconsistency in the effects of KCl on grain yield, prediction of KCl response can be a challenge. However, it appears as if some cultivars, such as AC Karma, are more consistent in their response to KCl application than are

TABLE 3. Spring wheat grain yield response to Cl fertilizer (40 lb Cl/A) addition across the sites and years in Brandon, MB.

	Fine sandy loam				Clay loam			
	1996	1997	1998	Mean	1996	1997	1998	Mean
Cultivar	Yield response, bu/A							
Canada Western Red Spring								
AC Barrie	7.5	7.0	5.7	**6.7**	-1.0	-0.2	0.5	**-0.2**
CDC Teal	-0.7	4.9	3.8	**8.0**	-5.2	-1.2	2.1	**-1.4**
AC Cora	5.0	-1.1	6.5	**3.5**	-0.1	0.4	1.6	**0.6**
AC Domain	5.0	-1.0	8.4	**4.1**	1.3	2.4	-1.3	**0.8**
AC Majestic	10.9	3.5	1.1	**5.2**	2.8	-1.8	1.6	**0.9**
Roblin	4.9	2.9	1.7	**3.2**	-3.6	-3.3	0.2	**-2.2**
U.S. Hard Red Spring								
Grandin	-5.5	-0.4	4.8	**-0.4**	-0.5	0.4	-0.9	**-0.3**
Pioneer 2375	6.6	2.2	1.9	**3.6**	-3.3	6.8	0.4	**1.3**
Marshall	0.4	3.0	0.6	**1.3**	-3.9	5.9	-3.0	**-0.3**
Guard	0.0	-3.0	6.2	**1.1**	0.5	5.8	-0.6	**1.9**
Canada Prairie Spring								
AC Karma	14.9	-4.8	6.7	**5.6**	8.5	10.2	6.3	**8.3**
AC Taber	-6.0	6.1	4.1	**1.4**	-0.4	-3.6	-2.2	**-2.1**
Canada Western Extra Strong								
Glenlea	-3.9	4.8	1.8	**0.9**	1.2	5.0	-1.7	**1.5**
Canada Western Amber Durum								
Kyle	7.4	-3.4	7.1	**3.7**	2.7	7.3	-1.1	**3.0**
Plenty	9.0	7.5	2.2	**6.2**	1.9	3.9	5.5	**3.8**

the majority of the cultivars evaluated in this study.

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Phosphorus Index...

(continued from page 19)

is shown in **Figure 4**. Results show that the PI for pastures closely predicted annual P loads from pastures receiving natural rainfall and poultry litter applications (r=0.91). These results confirm that the PI for pastures predicts P loads well under field conditions with natural rainfall.

Summary

Since P runoff from perennial pastures is predominantly soluble P, the SRP concentration in the source and the amount applied are more important than the total P content of the source. Validation studies showed the pasture PI predicts annual P losses very well from fields receiving natural rainfall.

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What Happened to 1966?

I can't believe it. Thirty-five years just flashed in front of my eyes. It couldn't have been that long since Pat and the kids and I piled all our worldly possessions into a (small) U-Haul trailer hitched to our old Mercury and headed to Atlanta for my first real job. We were uneasy about leaving Auburn University. We had set roots and established an extended family base among fellow graduate students during our nearly four years there. We were uncertain about the future.

Well, things have turned out just fine. As Pat and I make final preparations to leave Atlanta...on our way to retirement, we count ourselves blessed for having had the opportunity to spend 35 years in the fertilizer industry. My work has taken us from Auburn to Atlanta to Albany, Georgia, to Stillwater, Oklahoma, and back to Atlanta. Along the way, we have been privileged to travel to such diverse places as China, Australia, and France...and had the opportunity to meet, work with, and become friends with some of the finest people in the world.

One of the most difficult assignments in my career has been writing this page in *Better Crops with Plant Food* for the past couple of years. I'm humbled because there could never be another who frames his or her words in a more eloquent manner than did the late Dr. J. Fielding Reed, former PPI President. Between 1983 and 1999 he owned this space. Yet, it's a special honor for me to share the podium with Fielding.

This will be my last column as Executive Vice President of the Institute. However, Dr. David Dibb, PPI President, has asked me to continue with the page, so I hope you will visit me here for a while longer. In the meantime, I wish to express my appreciation to all my co-workers at PPI past and present. They have been the biggest reason...along with folks like Lance Murrell, Don Ball, Billy Darnell, Bob Westerman, and scores of other colleagues...that my job has been the best there is.

Pat says for me to not go around inviting everybody to come and see us at Amelia Island, Florida. I won't do that, but if you're ever in the area...

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