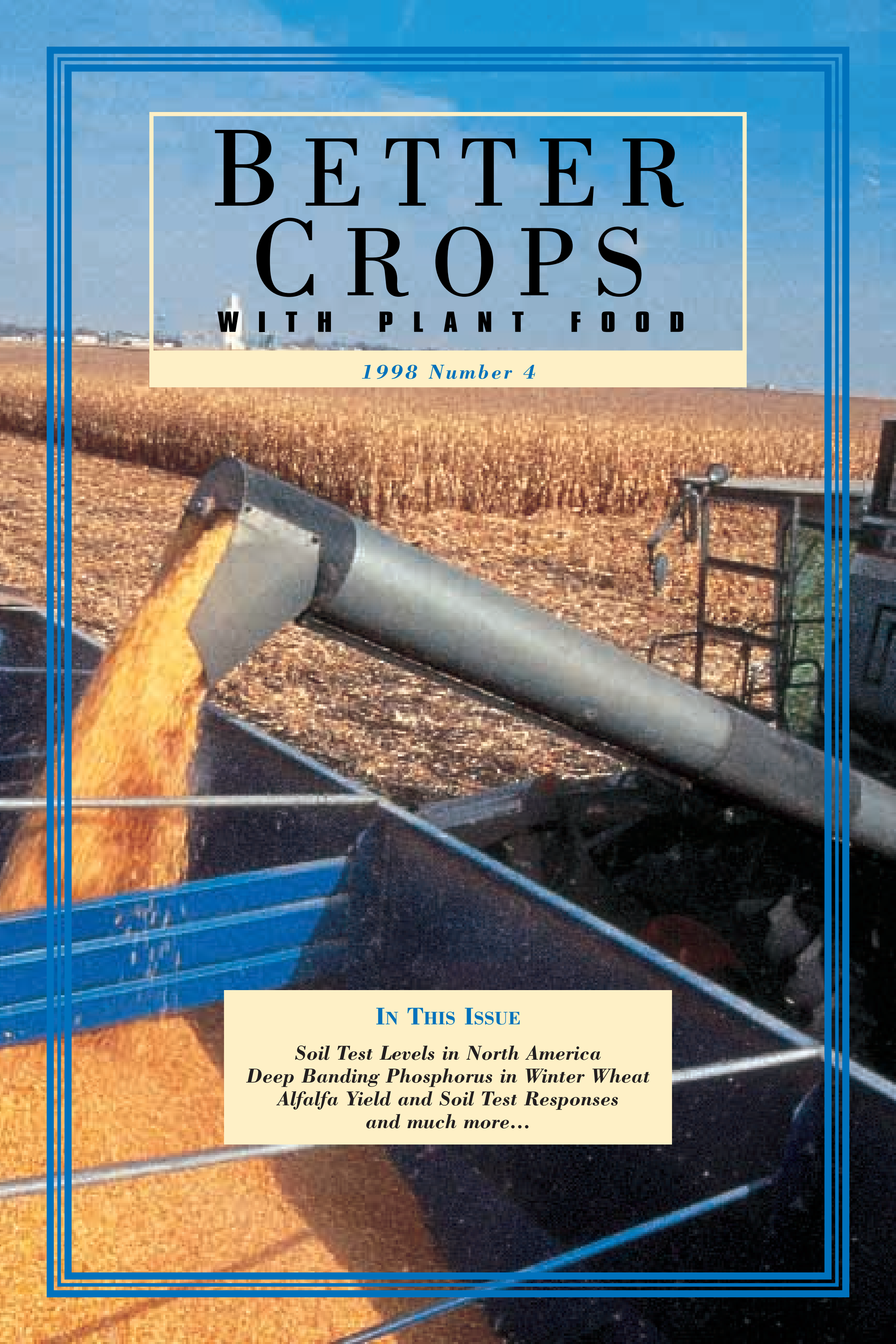
BETTER CROPS
WITH PLANT FOOD

1998 Number 4



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BETTER CROPS
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Vol. LXXXII (82) 1998, No. 4

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Alfalfa Yield and Soil Test Responses to Phosphorus and Potassium

By R.T. Koenig, C.L. Hurst, and J.V. Barnhill

Phosphorus (P) and potassium (K) fertilizer rate trials indicated pre-1997 Utah State University P and K fertilizer recommendations should be increased to reflect current yield levels and soil conditions. A higher critical soil test P value was also indicated, but more data need to be collected to identify the critical soil test K value. Soil sample depth and time of year have significant effects on soil test values and resulting fertilizer recommendations. These protocols must be standardized for routine sampling by farmers and agronomists.

Alfalfa is grown on about 7.4 million acres in the western U.S. and on more acres than any other crop in Utah. In the past, Utah P and K recommendations were based on alfalfa yields of 4 to 4.5 tons/A. Growers in many areas are now reporting yields as high as 8 tons/A. In addition, the frequency of low P and K testing soils has increased in alfalfa fields, and more visual symptoms of P and K deficiency have been observed by field agronomists and county agents.

The primary objective of this project was to evaluate P and K fertilizer recommendations for alfalfa and, if necessary, recalibrate the sodium bicarbonate ($NaHCO_3$) soil test for current crop yield potentials and soil conditions. A secondary objective was to evaluate the effects of sampling depth and time of year on soil test P and K levels and fertilizer recommendations.

Experiments were initiated at six sites between 1996 and 1998 (**Table 1**). Five of the sites were located in growers' fields, and one site (Cache) was located on a Utah State University Experimental Farm in Logan. Each experiment consisted of separate P and, if soil tests indicated a deficiency, K rate trials. Fertilizer rates of 0, 50, 100, 200, and 300 lb P_2O_5 or K_2O per acre were broadcast in late fall or early spring on established alfalfa stands. Each treatment was replicated three times in a randomized complete block experimental design. Yield and $NaHCO_3$-extractable P and K were measured for two a minimum of production seasons at each location.

Fertilizer rate effects. Yield ranged from 4.1 to 7.9 tons/A across sites. Annual responses to P fertilizer ranged from 0.6 to 1.9 tons/A. Pre-1997 Utah State University P recommendations were described as being for 2 to 3 years of alfalfa production. At sites where 2 full years of data are presently available, cumulative alfalfa yield responses occurred at P rates two to four times higher than pre-1997 recommendations (**Table 2**). At the lowest P testing site, the response to P rate was linear up to 300 lb P_2O_5/A. Responses to K ranged from 0.4 to 0.7 tons/A. Responses were higher than pre-1997 recommendations at two of three sites (**Table 2**). At the lowest K testing site, the response to K was linear up to 300 lb K_2O/A. Based on these results, Utah State University P and K fertilizer recommendations for alfalfa were increased in 1997 by 20 to 50 lb/A P_2O_5 or K_2O in each soil test category. Recommendations will be further refined as additional data are collected.

Fertilizer-soil test-yield correlations. The critical soil test P concentration (0 to 12 inch sample depth) was between 15 and 20 parts per million (ppm), as shown in **Figure 1**. This is higher than the previous critical value of 10 ppm used as a cutoff for fertilizer

TABLE 1. Selected soil properties of the P and K fertilizer rate study sites.

Location	Soil texture	pH	%CCE[2]	NaHCO$_3$-extractable[1] P, ppm	NaHCO$_3$-extractable[1] K, ppm
Cache	silt loam	7.8	37	9.0	95
Grand	loam	7.9	22	10.0	119
Sevier	clay loam	8.1	54	8.9	70
Weber	silty clay loam	7.1	0	4.2	105
Carbon[3]	loam	7.9	23	4.1	221
Uintah[3]	loam	7.7	4	7.7	179

[1] 0 to 12 inch sampling depth

[2] Calcium Carbonate Equivalent

[3] P-only site

TABLE 2. Pre-1997 Utah State University fertilizer recommendations and alfalfa responses to P and K fertilizer rates at three of the study sites. Results from the other three sites are being collected in 1998-1999.

County location	Pre-1997 P recommendation	2-year cumulative yield response	Pre-1997 K recommendation	1-year K response
	lb P$_2$O$_5$/A		lb K$_2$O/A	
Cache	40 to 60	200	80 to 120	100
Sevier	40 to 60	100	140 to 180	≥300[1]
Weber	70 to 90	≥300[1]	0	100

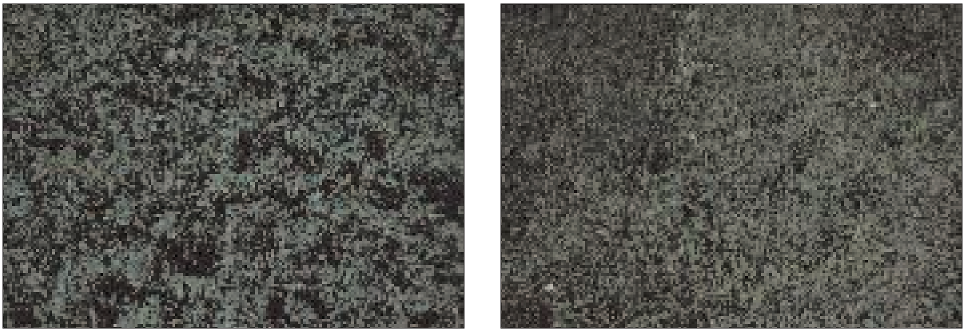
[1] Response was linear over the range of fertilizer rates evaluated.

recommendations. Considerable variability in soil test response to P application was evident among sites. For example, at the Sevier location the application of up to 300 lb P$_2$O$_5$/A increased soil test P linearly from 9 to 42 ppm (slope = 0.11 ppm P per lb P$_2$O$_5$/A), while at the Weber site the same rates of fertilizer increased soil test P linearly from 4.7 to 16.7 ppm (0.04 ppm P per lb P$_2$O$_5$/A).

At the Weber site, soil test P in the unfertilized treatment declined to 3.2 ppm after 2 years, and severe P deficiency symptoms were observed, as shown at right below.

A critical soil test K value could not be defined with the limited database currently available (**Figure 2**). At these sites it has been difficult to generate sufficiently high soil test K values with the range of K fertilizer rates applied. For example, at sites testing near or below 100 ppm K, the application of 300 lb K$_2$O/A produced soil test K values of only 85 to 122 ppm. Subsequent applications of 600 lb K$_2$O/A in 1997 increased soil test K from 93 to 111 ppm at the Weber site and from 79 to152 ppm at the Sevier site. These applications produced higher yields than the 300 lb K$_2$O/A treatment at both locations, but were not a part of the original treatment structure.

Soil test K in control (unfertilized) treatments at two locations has declined to 50 to 75 ppm after 2 years of cropping. At one site (Cache), low soil test K has lead to severe K deficiency symptoms and yield reductions of up to 40 percent in the first two cuttings of the 1998 crop year. Potassium deficiency



A P fertilized plot (left) and severe P deficiency in a control plot (right) at the Weber site (control plot soil test P = 3.2 ppm).

symptoms are shown in photo at right below.

The importance of P and K fertilization on low testing sites is clear. However, soil test responses to fertilizer application have been variable among sites. In addition, relationships among fertilizer rate, soil test value, and alfalfa yield have thus far been more difficult to define for K than for P. In addition to revising P and K fertilizer recommendations for alfalfa, we increased the critical soil test P concentration to 15 ppm and continue to work on identifying the critical soil test K concentration. Based on the variability in soil test response to fertilizer application among sites, we are now recommending that alfalfa growers soil test more frequently until deficiencies are corrected, especially on very low P and K testing sites.

Soil samples collected at 0 to 4 or 0 to 6 inch depths were 1.4 to 2.2 times higher in soil test P and 1.1 to 1.8 times higher in soil test K than 0 to 12 inch depth samples. As a result of the higher soil test values, sampling to depths less than 12 inches would result in inaccurate (lower) fertilizer recommendations. Since soil test correlation databases are based on a uniform 12 inch sample depth, routine soil sampling must be to the same depth in order to make accurate fertilizer recommendations.

Time of year also affected soil test P and K at two of the three sites evaluated. During the year, soil test values peaked in early spring, were lowest during midseason, and increased after alfalfa entered dormancy in fall. Depending on the site and time of year samples are collected, soil test values and the resulting fertilizer recommendations could vary considerably. BC

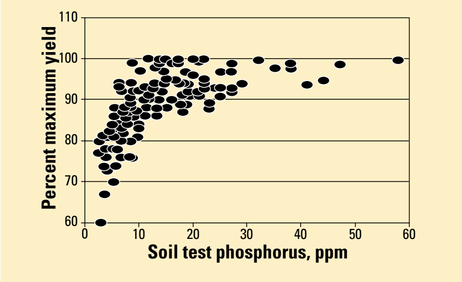


Figure 1. Relationship between soil test P and percent maximum yield. Data points are for 7 site-years.

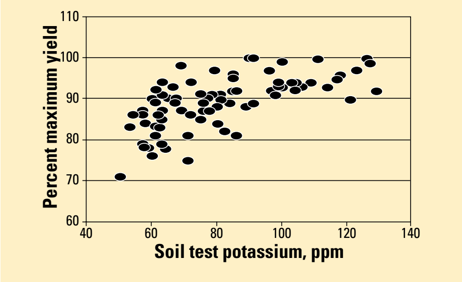


Figure 2. Relationship between soil test K and percent maximum yield. Data points are for 4 site-years.

Dr. Koenig is Assistant Professor and Extension Soil Specialist, Utah State University. Dr. Hurst and Mr. Barnhill are Utah State University Extension County Agents. E-mail address for Dr. Koenig: richk@ext.usu.edu

A K fertilized plot (left) and severe K deficiency in a control plot (right) at the Cache site (control plot soil test K = 53 ppm).

PRINCE EDWARD ISLAND

Phosphorus Needs of Processing Potato Varieties

By S. Moorehead, R. Coffin, and B. Douglas

Potato producers in PEI grow approximately 110,000 acres of the crop each year. While yields of this rainfed crop are not as high as in irrigated production in the West, high quality has led to renown for PEI potatoes. Nearly one half of the potato crop is processed, mainly for the production of French fries.

Phosphorus (P) is important for producing the large potato tubers desired for processing. Recent research in Prince Edward Island (PEI) has confirmed the high P needs of Russet Burbank, the most important processing variety, and has indicated that potato P needs may be variety-specific.

Producers typically apply 200 to 240 lb/A of P_2O_5 to potato crops. Since this is considerably more than the amount of P removed by the crop, soil tests are showing increasing levels of the nutrient in fields which have been used for potato production. Industry personnel have questioned whether the increased soil test levels would allow adjustment of rates of P applications and what the impact might be on the yield and processing quality of the different varieties. There are also questions on the impact of soil pH on optimum rate of P. Soils in PEI are typically acidic and high in iron (Fe), but producers apply lime to varying extents. There has been a dearth of local data collection in recent years to measure yield responses to levels of nutrients in soil (soil test/yield response calibration).

TABLE 1. Yield responses to applied P in 1992 and 1993 (mean of two years). Soil test P was 123 and 106 ppm.

P_2O_5 applied, lb/A	Marketable yield, cwt/A	
	Shepody	Russet Burbank
0	243	209
135	248	236
difference	6	27

The most popular variety for processing has been Russet Burbank, but it is a challenge to grow since it often requires a longer growing season than the PEI climate provides. In recent years the earlier maturing variety Shepody has become more popular. While it does not maintain its processing qualities in storage for as long a time as Russet Burbank, almost half of the processing crop is currently the Shepody variety.

To address the above questions, research on P needs was conducted from 1992 through 1994 and in 1997. The studies differed from year to year in the number of rates applied, but used similar production practices.

The most detailed study was conducted at two sites in 1997. Site A had clay loam soil with a relatively high pH of 6.0 to 6.2 and a Mehlich-III soil test level of 171 parts per million (ppm) P. Site B, located 10 miles away, had sandy loam soil at a lower pH of 5.5 to 5.7 with

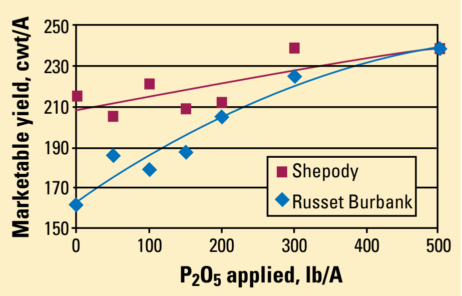


Figure 1. Yield responses to seven rates of applied P in 1994. Soil test P was 149 ppm.

a soil test level of 138 ppm P. Both sites followed a typical 3-year rotation (potatoes, barley, mixed hay).

At each site, four rates of P_2O_5 were applied (0, 65, 240, and 500 lb/A) to the two varieties, on limed (1 ton/A) and non-limed plots. All fertilizer was banded at planting. The sole source of P at the 65 and 240 lb rate was diammonium phosphate (DAP). A mixture of DAP and triple superphosphate (TSP) was used for the 500 lb rate. Nitrogen (N) rate was 150 lb/A, and potassium (K) rate was 240 lb/A K_2O. Ammonium nitrate [$(NH_4)NO_3$] was used to supplement N requirements from DAP. All K was provided from potassium chloride (KCl).

Results in 1992 and 1993 indicated that the Shepody variety was less responsive to applied P than Russet Burbank (**Table 1**). This was confirmed in 1994 (**Figure 1**), though both responded to some extent at the highest two rates.

In 1997, there was a surprising response to lime in both the lower and higher pH sites. In fact, results from the two sites were so similar that they were averaged together, as shown in **Figure 2**. Again, Russet Burbank responded more to P than did Shepody. Applying lime appeared to slightly enhance the P response for Russet Burbank, but it diminished the small response that Shepody showed in the non-limed treatment. On the low pH site, at about 75 days after planting, the pH within the hill had declined to 4.5 where no lime was added and to 4.8 even where lime was added. The pH dynamics may have influenced the availability of applied P.

Lime and P had no effect on specific gravity, the incidence of scab nor fry color when fried in mid November and mid February. Shepody tubers contained higher levels of P than Russet Burbank, 0.27 percent versus 0.22 percent, but lower levels of calcium (Ca), 164 ppm versus 222 ppm. Lime applications did not alter Ca levels in the low pH field, but increased Ca by 42 ppm in the high pH field.

Although soil test interpretations have changed over time, these soils were generally in the range considered to be medium to high in P. These experiments have confirmed the high P requirement of Russet Burbank grown on such soils. In addition, the lesser response of Shepody indicates that P needs for the potato crop may be variety dependent. For this reason, further research on potato P needs is important, and we are optimistic that a better crop can be produced using variety specific nutrient management.

Potatoes produced in Prince Edward Island have variety-specific P needs.

Mr. Moorehead and Dr. Coffin are with Cavendish Farms, Summerside, Prince Edward Island (PEI). Mr. Douglas is Soil and Feed Lab Supervisor, with PEI Agriculture and Forestry, Charlottetown, PEI.

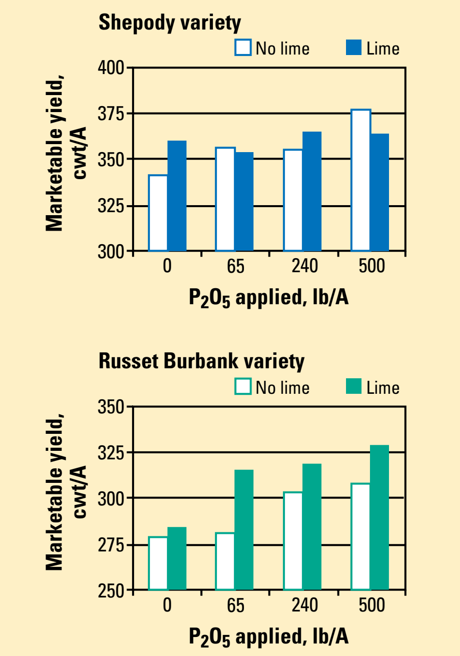


Figure 2. Yield responses to four rates of applied P in 1997, with and without lime application. Mean of two sites. Soil test P was 138 to 171 ppm P.

KANSAS

Profitability Surveys: Evaluating Management Factors

By T.L. Kastens, H. Nivens, W.M. Stewart, and T.S. Murrell

Economically, a well-managed firm is one that consistently makes greater profits than competing firms in the industry. In terms of production agriculture, good management is demonstrated by profits that are persistently greater than those of similarly structured, neighboring farms. It is therefore necessary, in analyses of profit, to identify management strategies that can be implemented consistently, regardless of yearly variation in other factors. Proven management practices are the ones that are best controlled and upon which producers should focus their attention.

Analysis of Kansas data shows that farm operators who want to improve profitability by improving management should focus on decreasing costs, faster technology adoption, and increasing yields.

The Department of Agricultural Economics at Kansas State University maintains an historical economic database of financial records from Kansas farms that are or have been members of one of six regional farm management associations. The database is referred to as KMAR, for Kansas Management, Analysis, and Research. Records from over 1,000 farms that were continuously enrolled from 1987 to 1996 comprise the data used in this study. This long-term database makes it possible to identify management practices that affect profitability.

The management variables analyzed were profit, yield, input cost, crop price, and adoption of one important technology. Profit was calculated by subtracting seed, fertilizer, marketing, herbicide, machinery ownership and operation, labor, and land costs from accrual crop income. The measure of profit ($/A) used in the analyses was calculated by subtracting the regional annual average profit from the farm's annual profit. Measured yields for a given year were converted to a percentage of regional average yields for that year. Crop input costs considered were machinery ownership and operating costs, crop labor, seed, fertilizer, herbicide, irrigation fuel, and interest costs. If the main crop (wheat, corn, milo, soybeans, and alfalfa) acres were greater then 50 percent of a farm's total crop acres, then annual cost for those crops was converted to a percentage of regional average cost for that year. Similarly, the actual market price at which a producer sold a crop was expressed as a percent of the appropriate region's average crop price. Technological adoption studied in this survey was the use of no-till and was measured by monitoring the replacement of labor and machinery costs by herbicide costs. A technology index was calculated as:

$$\text{Technology index} = \frac{\text{herbicide expense} - (\text{crop labor and crop machinery operation expense})}{\text{herbicide expense} + (\text{crop labor and crop machinery operation expense})}$$

When herbicide expense is zero, the technology index is -1. If labor and machinery costs were zero, the index would be +1. For each region, across 1987 to 1996, the technology index variable was regressed on years and the equation differentiated to determine the average rate of adoption over years for a particular region. This statistical model made it possible to determine each year how far ahead or behind each farm was, in years, compared to the average farm in that region and year.

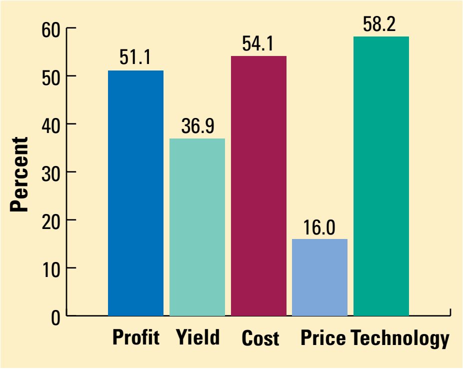


Figure 1. Percent of farms that consistently managed factors during 1987 to 1996.

TABLE 1. Variability of management measures: average value in high and low thirds.

Measure	High third	Low third
Profit, $/A	$79	-$80
Yield, %	17	-18
Cost, %	37	-28
Price, %	12	-11
Technology, years	17	-16

Identifying practices that can be consistently managed was accomplished by averaging a management measure's values for a particular farm over the 1987 to 1996 period and testing whether that average was statistically different from zero. The number of farms with long-term averages that were different from zero was then converted to a percentage of all farms in the survey. The results of this analysis are shown in **Figure 1**. This figure shows that 51 percent, 37 percent, 54 percent, and 16 percent of the farms in the survey consistently maintained either higher or lower profits, yields, costs, or prices, respectively. In addition, 58 percent of the farms were consistently faster or slower adopters of technology. These results indicate that it is easiest for a farm to differentiate itself from its neighbors by focusing upon technology adoption, cost, and yields (ignoring profit, which is more an end rather than a means to an end). The low persistence of price management suggests that it is especially difficult for a farm to achieve higher prices than those attained by other farms.

Survey participants were grouped into three categories for each management measure: high, middle, and low third. The mean of the management measures in the high and low third is presented in **Table 1**. This table shows that the high profit group averaged $79/A more than average. Similarly, those in the high third of yield or price were 17 and 12 percent higher than average, respectively. Those in the low third of costs were 28 percent better than average. **Figure 1** showed that it would be difficult to become a superior price manager. **Table 1** shows that even those who are good at pricing only get prices 12 percent higher than average. If one assumes that the typical price breaks even, then the cost row may be compared to the price row. This comparison indicates that it is much easier to achieve low costs (28 percent lower for the low third) than to achieve high prices (12 percent higher for the high third).

Those in the high third of technology

TABLE 2. Persistence across management traits (33.3% is considered random).

	This percent is in the...			
Of those in the...	**Highest third of yield**	**Lowest third of cost**	**Highest third of price**	**Fastest third of technology**
Highest third of profit	40.1	44.2	33.0	50.3
Highest third of yield		36.2	25.9	47.4
Lowest third of cost			34.4	49.1
Highest third of price				30.0

adoption were 17 years ahead of average. During the 1987 to 1996 period studied, the use of chemicals over tillage advanced slowly on average. Consequently, those farms that were principally no-till were calculated to be many years ahead of the average producer.

Management trends of the top third respondents are presented in **Table 2**. A random association between any two categories would be 33.3 percent. Therefore, percentages higher or lower than 33.3 percent indicate a possible relationship. High profits were associated with higher yield, lower costs, and faster adoption of new technology. Those in the highest third of profit were generally not better marketers of grain.

TABLE 3. Impact of individual management traits upon profit.

Marginal		**Best third**	
This change	**Results in this change in profit, $/A**	**This change**	**Results in this change in profit, $/A**
1% increase in yield	0.65*	17% increase in yield	11.05*
1% decrease in costs	0.72*	28% decrease in costs	20.16*
1% increase in price	0.14	12% increase in prices	1.68
1 year increase in speed of technology adoption	0.83*	17 year increase in speed of technology adoption	14.11*
10 acre increase in farm size	0.31*		

*Significantly different than zero at the 95% confidence level.

To determine the effect each management measure had upon profit, a multiple regression model was developed. This model determined the magnitude of the effects of yield, cost, price, technology, and farm size on profit. The results of this model are shown in **Table 3**. Based on profit impacts of being in the best third of a management category (right hand side of table), the most important factors for increasing profit were, in order: cost decreases, technology adoption (no-till), and increased yields. Increased price from marketing was not a significant factor. The marginal analysis (left side of table) showed that increased farm size had a significant impact on farm profitability, independent of the other management aspects measured.

The results from this study show that operators who wish to improve profitability by improving management should focus upon decreasing costs, faster technology adoption, and increasing yields. In this study, no-till adoption was used to measure the rate of technological adoption. If a new agricultural technology, for example precision agriculture, is thought similar to the no-till technology studied here, then prudent managers should consider getting involved early – unless they believe that the new technology is not here to stay. It is important to remember that early adopters garner the profits associated with a new technology. Once the technology becomes established, profits disappear. However, greater profits often come with greater risks, and a wise manager will balance risk and profits in a way that provides the desired comfort level and profit.

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Announcement:

The 1999 Information Agriculture Conference (InfoAg99) is scheduled for August 9, 10 and 11 at Purdue University, West Lafayette, Indiana.
More details at www.ppi-far.org

NORTH CAROLINA

Variable Rate Nutrient Management for Corn-Wheat-Soybean Cropping Systems

By R.W. Heiniger

What are the benefits of variable rate application and site-specific nutrient management? Research in North Carolina is comparing uniform and variable rate treatments for corn-wheat-soybeans. Economic analysis indicates increased profit potential where variability exists in fields.

A research site was established on a field on Open Grounds Farm, Inc. It included four different soil types which ranged from Ponzer muck to a Tomotley sandy loam. Corn yield potential for each of the soil types as reported in the Natural Resource Conservation Service (NRCS) soil survey did not differ greatly (**Table 1**). However, data collected by a combine yield monitor over the past 3 years showed an 80 bu/A difference among the soil types (**Table 1**). Furthermore, corn and soybean yields were clearly related to soil texture in this field.

A strip plot trial was set up with uniform and variable rate nitrogen (N) as the treatments. In addition, small replicated plots were established to examine a range of N rates for each soil type represented in the field. In the variable rate strips, N was varied by soil type (**Table 2**). Recommendations were made using normalized yields from the 3 years of yield data and the equation:

N recommended = normalized yield factor for soil type
x average whole field yield for corn x 1.25

Uniform rates for N were based on the whole field average yield. Early differences between the strips were noted in aerial photographs and with a chlorophyll meter. Because growing conditions at this site were ideal, corn responded well to N fertilization.

Preliminary analysis of the yield data shows that the variable rate and uniform rate treatments had similar yields (**Table 2**). Where the variable rate application resulted in more N applied, yields were higher than the uniform rate. However, on the Ponzer Muck soil where the uniform rate resulted in more N applied, yields were higher on the uniform strips than on variable rate strips. The overall results showed no advantages to variable rate N application either in reducing the amount of N applied or in increasing corn yield. Clearly, further study is needed on these systems to better determine yield potential for different areas in a field. Yield potential as determined in this study proved to be too low for the good growing conditions encountered.

These results prove that before nutrient management plans can be done for N, a thorough understanding of the yield potential at the site is required. They also show the importance of yield measurements across a number of years.

If site-specific management of nutrients is to become a widely accepted practice, it

TABLE 1. Soil map units, classification, and corn yield potential as reported by NRCS and from farmer field history.

Soil map units	Soil survey yield potential, bu/A	Farmer yield history, bu/A
Belhaven muck	135	100
Ponzer muck	135	100
Wasda	135	140
Deloss sandy loam	135	180
Tomotley sandy loam	130	180

TABLE 2. Nitrogen applied and yield returns from variable and uniform management of N fertilizer across different soils, 1997.

Area measured	Site-specific management N rate, lb/A	Site-specific management Yield, bu/A	Uniform management N rate, lb/A	Uniform management Yield, bu/A	Statistical difference
Whole field	186	165	185	171	NS
Ponzer soil	125	151	185	182	***
Wasda soil	185	176	185	176	NS
Deloss soil	230	174	185	166	NS

***P<0.05

must be proven to be either cost effective or to have some environmental benefits that justify the extra expense involved in sampling and applying nutrients differentially across a field. Unfortunately, side-by-side comparisons of site-specific versus uniform nutrient management are lacking. This is due to the difficulty in identifying matching field conditions for comparing both practices.

A study site with consistent field conditions across a large area was identified in eastern North Carolina in 1997. Intensive soil sampling on 100 ft. x 800 ft. grids was done to determine nutrient levels, pH, and other soil properties. The field was then divided into 16 subunits each with matching soil conditions. Eight of the subunits were randomly selected to receive site-specific applications of phosphorus (P) and potassium (K), and eight were selected to receive uniform applications. Yields were measured with a grain yield monitor. Comparisons were made between the two fertilizer treatments to determine their effects on grain yields.

Tables 3 and **4** show a comparison between site-specific and uniform P and K management. Under site-specific management total P applied increased (**Table 3**) while less K was required (**Table 4**).

If we consider the distribution of nutrient levels within a field we can see why this could happen. Whenever the average of all soil tests sites is greater than the median or mid-point, there will be an increase in the amount of fertilizer applied using site-specific grid sampling. This happens because the number of samples that test low are overshadowed by a few high to very high samples.

TABLE 3. Comparison of site-specific and uniform P management (DAP @ 11.25¢/lb).

P index	Acres	Grid sample DAP, lb	Grid sample Cost, $	Uniform sample DAP, lb	Uniform sample Cost, $	Difference, $
0-12.5	25.8	6,493	730.46	1,786	200.93	529.53
12.5-25	16.6	2,948	331.65	1,147	129.04	202.61
25-50	61.6	2,694	303.08	4,260	479.25	-176.17
50-75	20.4	0	0	1,413	158.96	-158.96
75-100	1.1	0	0	76	8.55	-8.55
Totals	125.5	12,135	1,365.19	8,682	976.73	388.46

TABLE 4. Comparison of site-specific and uniform K management (0-0-60 @ 13.75¢/lb).

K index	Acres	Grid sample 0-0-60, lb	Grid sample Cost, $	Uniform sample 0-0-60, lb	Uniform sample Cost, $	Difference, $
0-12.5	0	0	0	0	0	0
12.5-25	4.5	715	98.31	665	91.44	6.87
25-50	82.5	11,245	1,546.18	12,183	1,675.16	-128.98
50-75	35.5	1,893	260.28	5,242	720.78	-460.50
75-100	3.0	0	0	443	60.91	-60.91
Totals	125.5	13,853	1,904.77	18,533	2,548.29	-643.52

TABLE 5. Yield differences between areas of two 125-acre cuts with various soil test P levels, 1997.

P index	Recommended P_2O_5	Acres	Yield, bu Variable	Yield, bu Uniform	Yield, bu Difference
0-12.5	122.5	25.8	4,231	3,870	361
12.5-25	74.5	16.6	2,639	2,058	581
25-50	18.1	61.6	9,979	9,917	62
50-75	0	20.4	3,427	3,468	-41
75-100	0	1.1	191	196	-5
>100	0	0	0	0	0
				Total yield difference, bu	958

TABLE 6. Cost profit analysis for variable rate vs. uniform fertilizer application.

Operation	Cost, $ Grid sample	Cost, $ Uniform sample	Difference, $
Phosphorus	1,365.19	976.73	-388.46
Potassium	1,904.77	2,548.29	643.52
Additional yield income	2.20/bu	X Yield diff. (958 bu)	2,107.60
Cost of soil sampling	1,004.00	251.00	-753.00
Variable rate spreader	376.50	0	-376.50
		Profit advantage to variable rate	1,233.16

Net return to site-specific fertilizer application. Costs include soil sampling on 2.5-acre grids and a $3.00/A charge for variable rate application. Net return/A is $16.35.

Since the average nutrient value is increased by the few high testing samples, there is a tendency to under-fertilize with the uniform application strategy. In comparison, when most of the samples test high, but with a few very low testing samples, the average soil test is low. In this case, site-specific nutrient management will result in less fertlizer used.

Another way to increase profits by using site-specific nutrient management is to increase yields. **Table 5** shows results from two fields. Nutrients in the first field were site-specific applied using grid samples, while nutrients in the second were uniformly applied using an average soil sample. Site-specific nutrient applications increased yields in the areas of the field testing low in P. This resulted in an overall profit of $1,233.16 on 125 acres or $9.87 more profit per acre using site-specific nutrient management (**Table 6**).

Site-specific fertility management can pay as long as nutrient variability exists within a field. Furthermore, studies have shown that even under site-specific nutrient management, soils that test low in P or K tend to always need more of these nutrients. Therefore, variable rate applications should be tailored to meet nutrient requirements over time.

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SASKATCHEWAN

No-till Management Requires Proper Fertilization

By C.A. Campbell, G.P. Lafond, R.P. Zentner and T.L. Roberts

> The adoption of no-till management will hasten the negative effects of poor fertilizer management. Not only will yields be reduced, but soil organic matter may decline in unfertilized no-till systems. Growers who are adopting no-till cropping systems need to soil test and apply recommended nutrients. Proper fertilization is imperative to the optimization of production and maintenance of soil organic matter.

Producers switching to a no-till cropping system must maintain adequate fertility. Otherwise, yields could suffer, and in time soil organic matter may decline. This was evident in a long-term crop rotation study, initiated in 1957, on a fertile Black Chernozemic clay soil at Indian Head, Saskatchewan, in which tillage was changed from conventional to no-till in 1990.

Figure 1 shows that from 1953 to 1989, while conventional mechanical tillage was practiced, wheat grown on fallow required very little nitrogen (N) fertilizer (**Figure 1d**). Consequently, there was no difference in yields due to fertilizer (**Figure 1a**). Once we changed to no-tillage in 1990, soil N mineralization in the 20-month fallow period was suppressed, so that fertilizer N requirements for fallow crops was markedly increased (**Figure 1d**), and the yield advantage of the fertilized system over the unfertilized system became quite substantial (**Figure 1a**).

Fertilizer N requirements for wheat grown on stubble have not changed much with the change in tillage (**Figure 1d**). This is because, prior to 1990, these systems received only one preseeding tillage compared to an average of four tillage operations for fallow-wheat. Thus, for the stubble crop systems we see a gradual upward trend in yields of fertilized systems and a slight downward trend in yields of unfertilized systems (**Figures 1b** and **1c**).

These results suggest that by curtailing the frequent soil stirring associated with tillage during the fallow period, we severely reduced the amount of N released from organic matter during this period. The resulting lower soil tests led to the greater requirement for fertilizer. The degrading effect of fallowing, compared to the aggrading conditions of continuous cropping has been reflected in greater N fertilizer requirements for the stubble crop in fallow-wheat-wheat (F-W-W) than for continous wheat (Cont. W) in recent years (1987-1994).

The problem does not end with poorer grain yields, and likely lower protein. It also leads to lower soil organic matter in the long-term (**Figure 2**). Lower grain yields mean less crop residues. Crop residues provide the raw materials for building soil organic matter. The impact of the change to no-tillage was evident when we compared soil organic carbon (SOC) before and after the change to no-till. The systems fertilized with N plus phosphorus (P) were able to maintain SOC, but the unfertilized wheat rotations actually lost SOC. For example, all three unfertilized rotations lost about 1 ton SOC per acre between 1987 and 1996, 6 years after the change to no-till, while SOC in the fertilized systems remained relatively constant.

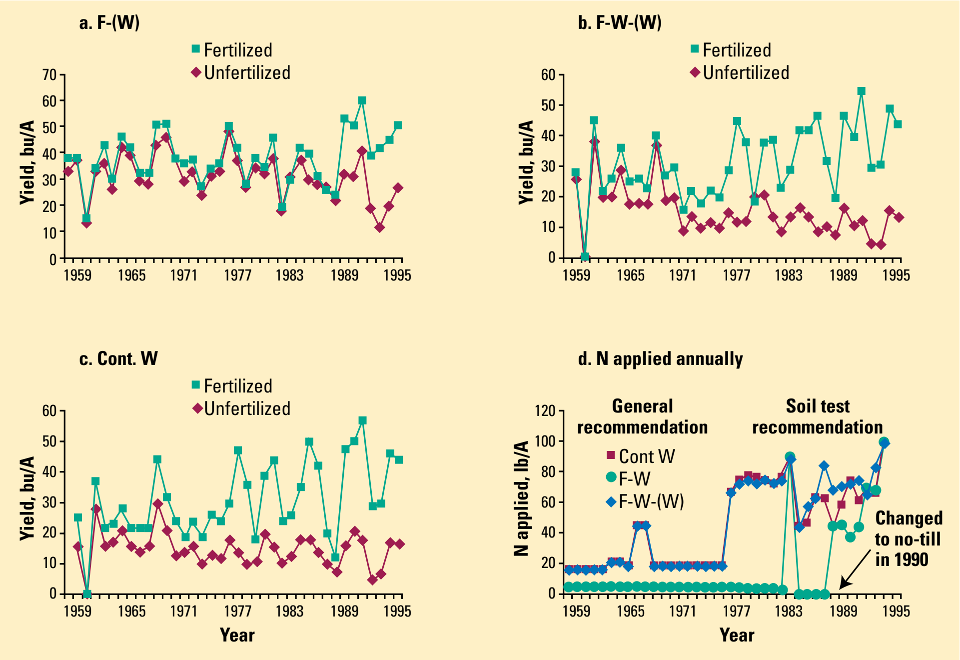

Figure 1. Effect of N and P fertilization and change to no-till management after decades of conventional tillage on spring wheat yields in: a. in fallow-wheat (F-W), b. fallow-wheat-wheat (F-W-W), c. continuous wheat (Cont. W), and on d. annual rates of N applied (rotation phase sampled in parenthesis).

We had expected the introduction of no-tillage (because it increases available soil moisture) to enhance soil SOC, especially in the fertilized systems. It has not done this. It may be that any positive contributions due to increased crop residues are being counterbalanced by greater rates of organic matter decomposition in the more moist soil conditions. BC

Dr. Campbell, Dr. Lafond, and Dr. Zentner are Research Scientists with Agriculture and Agri-Food Canada, located at Ottawa, ON, Indian Head, SK, and Swift Current, SK, respectively. Dr. Roberts is PPI Western Canada Director, located at Saskatoon, SK.

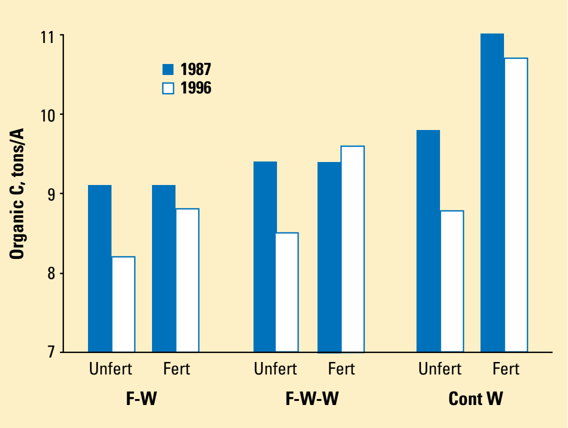

Figure 2. Effect of cropping frequency and fertilizer N+P on SOC in the 0 to 3-inch depth after 30 and 39 years.

SUMMARY UPDATE

Soil Test Levels in North America

By P.E. Fixen

This summary includes results of tests performed on more than 1.8 million soil samples collected in the fall of 1996 and spring of 1997. Soil test data are reported as the percent of samples analyzed that tested medium or below in phosphorus (P) or potassium (K) or had pH values less than or equal to 6.0. These are soil test categories where most agronomists would predict a significant yield response in the year of application to P, K or lime. Most state or provincial supported laboratories that perform a significant amount of agricultural soil testing submitted data for the summary. Several private laboratories also submitted usable data.

With the assistance of numerous public and private soil testing laboratories, PPI periodically summarizes soil test levels for phosphorus (P), potassium (K), and pH in North America. This 1997 summary is the seventh completed by PPI, the first dating back to the late 1960s.

Certain weaknesses exist in the summary process. They should be considered in interpreting and using the results of the summary. Weaknesses include:

- The agronomic definition of medium is not consistent, but varies among laboratories due mostly to differences in philosophical approaches.
- Quantity of samples was low in some states and provinces.
- Some areas of each state or province are likely under or over represented.
- It is likely that the better managers soil test and that their soil tests are higher than the average.
- Home and garden samples frequently could not be separated from agricultural samples. Since these average considerably higher than agricultural samples, they contribute to an upward bias.
- A growing bias is introduced in summaries as the amount of intensive soil sampling associated with site-specific management increases. A sample representing one acre has the same weight as a sample representing 40 acres.

There are many advantages to high P and K soil test levels. They are important in providing plants with needed nutrients to take advantage of optimum growing conditions and reduce the negative effects of stressful conditions. High soil P and K levels provide protec-

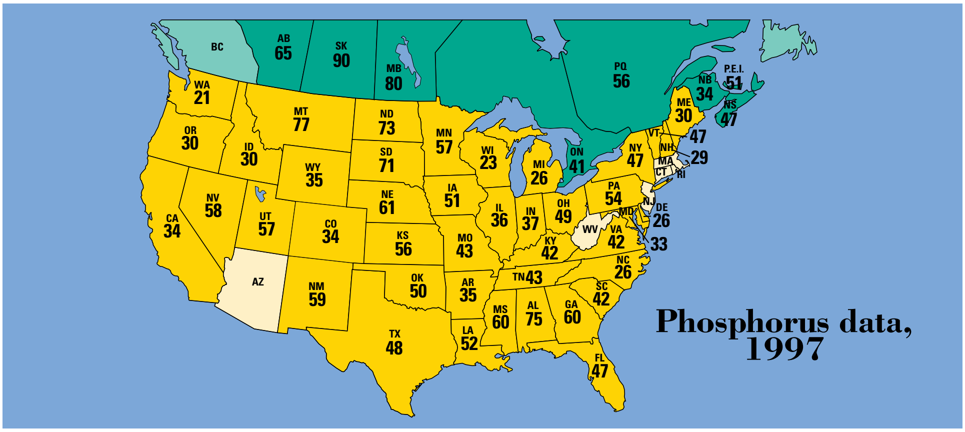

Figure 1. Phosphorus soil test summary – percent testing medium or lower.

tion against deficiencies induced by nutrient stratification in reduced tillage systems plus more options in fertilizer placement, time of application, nutrient application rates, and frequency of soil sampling. High and very high field average soil test levels offer insurance against profit-robbing deficiencies occurring in low testing parts of variable fields. Considering the very high frequency of extreme within-field variability revealed by intensive sampling, this factor alone in many cases justifies building soil test levels to at least the high category.

Because of the factors discussed above, the categories of medium or lower generally represent soils where current P and K use is barely adequate or inadequate...where increasing use above current levels will very likely increase long-term profitability by building soil fertility to a more optimum level. At the same time, it is important to recognize that these nutrients should be protected from loss to avoid environmental degradation. This can be accomplished through proper management. It should not be assumed that because a soil area or field is high in fertility that it represents a threat to water quality or because it is low in fertility that it offers no threat to water quality. Management relative to watershed characteristics makes the difference.

It should not be assumed that because a soil area or field is high in fertility that it represents a threat to water quality or because it is low in fertility that it offers no threat to water quality. Management relative to watershed characteristics makes the difference.

Of the entire 1.8 million soil samples in this summary, 46 percent and 44 percent tested medium or below in P and K, respectively. As expected, considerable variation existed among states and provinces (**Figures 1** and **2**). The Northern Great Plains had the highest frequency of medium or below P tests in the 60 to 80 percent range while a few states scattered around the U.S. fell in the 20 percent range. East of the Mississippi River, 16 of 23 reporting states had 50 percent or more of the K tests in medium or lower categories. Western states and provinces generally had fewer soils in the medium or below K categories than those in the East. The higher K levels of the West reflect the less weathered status of western soils. However, in states such as California where 48 percent of soils test medium or below in K, crop removal over several decades with limited potash addition has significantly reduced soil K levels.

Liming to neutralize soil acidity has long been recognized as one of the foundations of crop production. Increasing soil pH by liming provides a means of improving nitrogen (N) fixation by legumes, improves the availability of other nutrients such as P, and lowers the toxicity of aluminum and manganese.

Soil test summary information for pH is shown in **Figure 3**. A pH of 6.0 was selected as a breaking point for this summary because

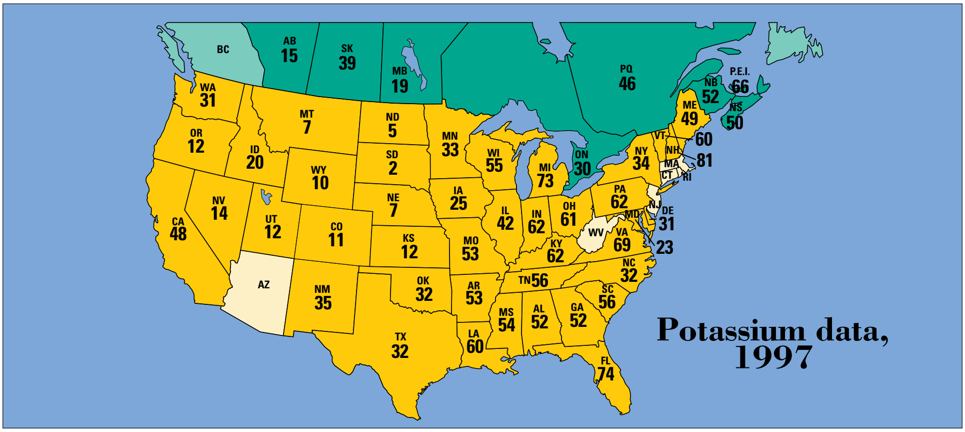

Figure 2. Potassium soil test summary – percent testing medium or lower.

soil pH above 6.0 is desirable for most cropping systems. Historically, soil pH values have tended to be more acid where rainfall is higher and where large amounts of vegetation have helped to acidify the soil. Those conditions have been associated with areas east of the Mississippi River in the U.S. and in the eastern Canadian provinces. However, continued research has revealed that soil acidity problems are not limited to those areas. The highest frequency of soil acidification continues to be found in the southeast where, in some states, over 60 percent of the soils test below pH 6.0.

Conclusions

The common perception that soil test P and K levels are seldom yield limiting in North America is wrong. As indicated earlier, approximately 45 percent of soil samples are currently testing medium or below in P or K. Furthermore, historical trend lines suggest that in many key agricultural states, this percentage is **not** currently decreasing and may even be on the increase. For example, the values for percent medium or below in P or K reached low points in the 1989 summary for the Illinois-Indiana-Ohio region and appear to be on the rise in the 1993 and 1997 summaries. Levels are now approaching the values reported in the first summary for this region in 1975.

In other states and regions, often where animal manure production relative to available land for application is high, percent medium or below in P has been steadily declining throughout the entire sumary period. State nutrient budgets that account for nutrients removed in crops and animals as well as the nutrients applied as fertilizer and potentially applied as manure appear to help explain the differences among states in general soil fertility trends.

Nutrient management should occur on a site-specific basis where the needs of individual fields, and in many cases areas within fields, are recognized. Therefore, a general soil test summary like this one has little value in on-farm nutrient management. Its value lies in calling attention to broad nutrient needs, in motivating educational and action programs, and in reminding individual farmers of the importance of a soil testing program to monitor soil nutrient status. BC

Dr. Fixen is PPI Senior Vice President and North American Program Coordinator, located at Brookings, South Dakota.

More detailed information is included in Technical Bulletin 1998-3, available for purchase from PPI...fax (770) 448-0439.

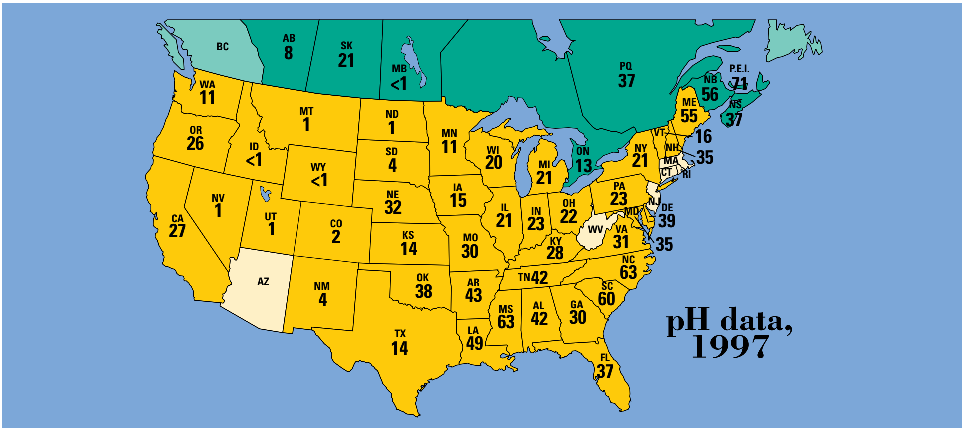

Figure 3. Soil test summary for pH – percent testing 6.0 or less.

ARKANSAS

Decreasing Phosphorus Runoff from Poultry Litter with Aluminum Sulfate

By M.L. Self-Davis and P.A. Moore, Jr.

Many recent studies conducted at the University of Arkansas and across the nation have focused on identifying best management practices (BMPs) to alleviate the problems associated with excessive P build up in the soil. An effective practice identified in recent research involves the addition of aluminum sulfate (alum) to poultry litter.

> Poultry litter has long been recognized as a valuable nutrient source for crops and pastures. However, poultry litter has a fairly consistent nitrogen (N) to phosphorus (P) ratio of about 2:1. Since the recommended application rate is often based only on the N requirement of the crop, P may be applied in excess of crop demand, increasing the potential for off-site loss through runoff and erosion.

Arkansas Studies-Phosphorus Management

Previous studies conducted at the University of Arkansas have shown that when poultry litter is surface-applied to a pasture, 80 percent or more of the P in the runoff is in the dissolved or soluble form. Therefore, one way to reduce P in runoff would be to add a chemical amendment to the litter, converting the P to a less soluble form. It was shown in laboratory studies that the addition of alum to poultry litter is extremely effective in decreasing the solubility of P in poultry litter. Building on this information, a field study was initiated at the Main Agricultural Experiment Station of the University of Arkansas. Alum treated litter and normal (untreated) litter were applied at a rate of 5 tons/A to tall fescue plots. Two rainfall simulations, each at 2 inches per hour for 45 minutes, were then conducted (2, 6 and 9 days after litter application), and runoff samples from the plots were collected. Soluble reactive P concentrations in the runoff water were 87 percent lower from the alum-treated litter plots compared to the untreated litter plots for the first runoff event, and 63 percent less for the second. Total forage yields showed the greatest response to application of alum-treated litter. The yield response was most likely due to an increase in available N resulting from decreased ammonia (NH_3) volatilization from the alum-treated litter.

Additional research on runoff P from pastures was done on a field scale level at a commercial broiler farm in northwest Arkansas. Six commercial broiler houses are located on the farm; three houses were treated with alum at the end of each growout, and the other three houses were used as controls (received no chemical amendments). All six houses were managed as typical commercial broiler houses, with six growouts per year, each growout lasting approximately 6 weeks. At the farm site, two one-acre watersheds were built and instrumented with automatic water samplers in order to collect runoff that occurs from storm events. In 1995, each watershed received a 2.5 ton/A application of litter. In 1996 and 1997 the application rate was 4 tons/A. One watershed received litter from the poultry houses that had been treated with alum, and the other watershed received litter from the poultry houses used as controls. The poultry litter was applied in the spring of the year (April or May) as is the typical practice in northwest Arkansas. The forage produced on the watersheds was either harvested as hay or mowed and left on the surface. The watersheds were not grazed.

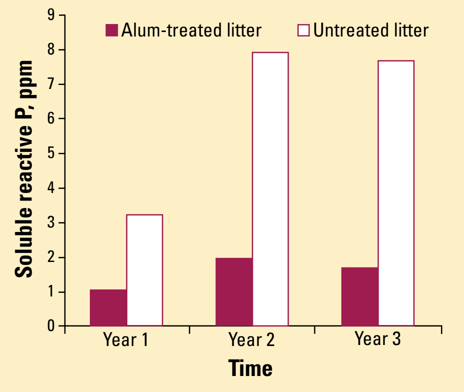

Figure 1. Soluble reactive P concentrations in run-off from each watershed.

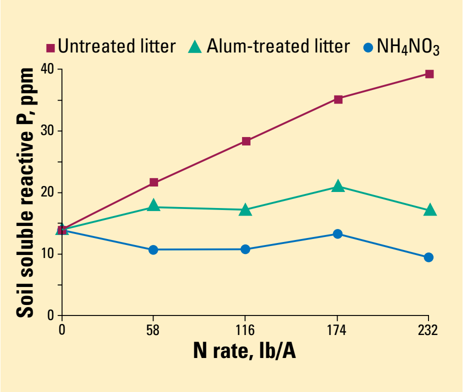

Figure 2. Soil soluble reactive P concentrations, June 1997.

Figure 1 shows the soluble reactive P concentrations in parts per million (ppm) in runoff samples from each watershed. The data in this graph represent all runoff events for the year averaged together to calculate the mean concentration value. Soluble reactive P concentrations in the runoff from the watershed treated with alum-amended litter remained consistently low each year and were much lower than the runoff from the watershed treated with untreated litter. The runoff samples were also analyzed to determine runoff aluminum (Al) concentrations. There were no differences in Al concentrations in runoff between the watershed receiving alum-treated litter and the watershed receiving untreated litter.

Although these studies concluded that alum is extremely effective in reducing the amount of P in runoff, there was still a question about its effects on soil test P levels. To address this question, an additional small plot study was conducted at the Main Agricultural Experiment Station of the University of Arkansas. The study used 52 tall fescue plots where 13 different treatments were applied. There were four replications of each treatment. The 13 treatments were: untreated litter and alum-treated litter (10 percent alum by weight) at application rates of 1, 2, 3, and 4 tons/A; ammonium nitrate (NH_4NO_3) at 58, 116, 174, and 232 lb N/A; and an unfertilized control. The NH_4NO_3 rates were equivalent to the rates of N applied with alum-treated litter. Each treatment was applied in the spring of the year for 3 years. Soil cores (0 to 2 in.) were taken periodically throughout the study and extracted for water soluble P. **Figure 2** shows the results from June 1997, after 3 years of litter and fertilizer treatment applications. Water soluble soil P levels in all plots treated with alum-treated litter, regardless of the application rate, were not significantly different than soil P levels in the unfertilized control plots. Plots that received the untreated poultry litter had the highest soil test P levels, and these levels increased as the application rate of the litter increased. Plots treated with the NH_4NO_3 had the lowest soil test P values.

Additional Benefits

Other studies have shown that P is not the only nutrient reduced in runoff when poultry litter is treated with alum. Runoff studies at the University of Arkansas have demonstated that copper (Cu) and zinc (Zn) concentrations in runoff from plots treated with poultry litter can be high enough to cause potential problems. In a study that compared metal concentrations in runoff between plots receiving untreated litter and alum-treated litter, it was determined that alum can reduce the concentrations of arsenic (As), Cu, iron (Fe), and Zn. This is an additional environmental benefit, since these trace metals can cause problems in aquatic environments.

The practice of treating poultry litter with alum is environmentally beneficial. It can also mean increased profits for poultry producers.

Alum spread on litter in poultry houses offers several benefits.

Ammonia volatilization results in high levels of NH_3 gas in the atmosphere of poultry houses, which can be harmful to the health of birds and farm workers.

In order to test the effects of adding alum to poultry houses to reduce NH_3 volatilization, two broiler farms were chosen...one had six houses, the other four houses. The litter in all of the houses was removed at the beginning of the study and replaced with fresh wood shavings. After each growout, the litter was de-caked using a commercial de-caking machine, and alum was applied in half of the houses on each farm. The other houses were controls. The rate of alum used was 4,000 lb/house after each growout.

Reductions in litter pH decreased NH_3 volatilization from the litter, which resulted in significant reductions in atmospheric NH_3 in the alum-treated houses compared to control houses. Ammonia fluxes were reduced 99 percent by alum for the first four weeks of the growout. These lower NH_3 levels resulted in significantly heavier birds in houses treated with alum than the controls (3.65 lb for control birds and 3.80 lb for birds grown on alum-treated litter). Mortality tended to be lower (3.9 vs. 4.2 percent), and feed conversion (1.98 vs. 2.04) was better for birds grown on alum-treated litter compared to controls. Energy usage was also lower, with propane use approximately 11 percent lower and electricity use 13 percent lower for the houses treated with alum. Tabulating all the savings listed above by using alum, the total benefit to the grower and integrator would be approximately $940.00 per house per growout. The cost of using alum, including the application and incorporation, is approximately $480.00 per house per growout. Therefore, the benefit /cost ratio of this practice is 1.96, indicating that it is very cost-effective.

Summary

Applying alum to litter is a relatively simple and cost effective way to help alleviate environmental concerns associated with the use of poultry litter as a fertilizer. Alum treatment resulted in an 80 percent reduction in mass loss of P from the site in the first year. It is effective at reducing P and trace metal concentrations in runoff from fields where poultry litter has been applied. The use of alum-treated litter also results in lower soil test P values compared to untreated poultry litter. Alum additions during the growout process also greatly reduces NH_3 volatilization, resulting in an economic benefit to the producer. BC

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A L B E R T A

Nitrogen and Phosphorus Optimize Barley Silage Production

By R.H. McKenzie, A. Middleton, E. Solberg, J. DeMulder, and H. Najda

Feed demands for Alberta's livestock industry result in some 800,000 acres of barley silage production each year. Farmers want high yielding, good quality silage, but have little information about the nutrient needs of today's varieties. We initiated a three-year study to evaluate the yield potential and fertilizer requirements of several new barley cultivars grown under irrigated and dry land conditions at 10 to 12 sites in Dark Brown, Black, Thin Black, and Gray-Wooded soils across Alberta.

Barley silage is highly responsive to nitrogen (N) and phosphorus (P) fertilization. Varieties differ greatly in their dry matter production and quality, and response to fertilization is variable, depending on the agro-climatic area. Phosphorus fertilizer is essential for optimum production, especially when soil test levels are low.

Nitrogen Fertilization

Barley silage has a high demand for plant nutrients. A typical crop will remove 130 to 180 lb of N, 40 to 60 lb of P_2O_5, 110 to 140 lb K_2O and 15 to 20 lb sulfur (S) per acre. Barley silage is very responsive to N fertilization. Yields can exceed 7.5 tons/A under irrigation and 5 tons/A for dry land, if adequate N is supplied (**Figure 1**). About 110 lb/A N is needed to optimize yields under dry land when soil test levels are low to medium. Nitrogen rates may approach 140 lb/A under irrigation, but lodging can be a problem in high yielding varieties at the higher application rates.

Silage protein is also highly responsive to N fertilization. Protein concentration increased linearly with N applications up to 180 lb/A. However, considerable differences existed among varieties (**Figure 2**). Unfertilized controls had less than 10 percent protein, but depending on the variety, protein concentration could be increased by 50 percent or more at the higher N rates.

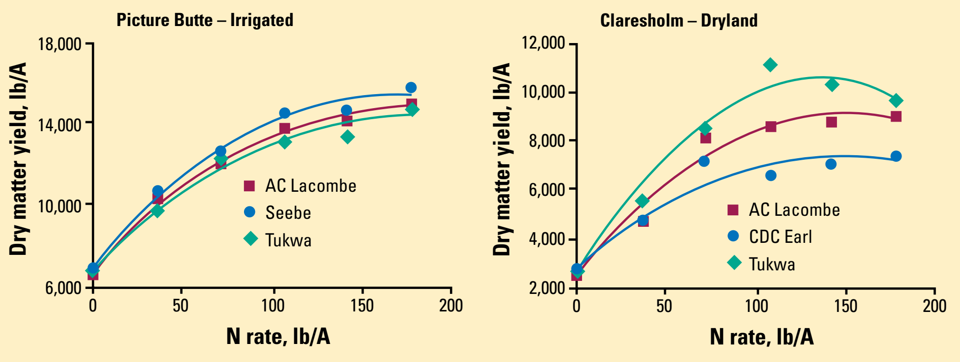

Figure 1. Dry matter silage production of several barley varieties under dryland and irrigation at two locations in Alberta.

Phosphorus Fertilization

Phosphate fertilizer significantly increased silage yield at 25 of 32 site-year locations. Similar to N, varieties responded differently to applied P. Some varieties responded to P fertilization regardless of soil test level. However, when soil test P was 10 parts per million (ppm), or less, P increased yields at all sites except one. More than 70 percent of the sites responded to P fertilization when soil test P was between 10 and 20 ppm. When soil test P was above 20 ppm, the frequency of response was less than 40 percent. **Figure 3** shows the magnitude of response observed to 60 lb/A P_2O_5 at three locations in different agro-climatic areas. Applied P commonly increased yield by about 25 percent, but occasionally response was much higher. For example, P increased the dry matter yield of AC Certa from 6,812 lb/A to 14,483 lb/A at a location in the Black soil zone (data not shown).

Phosphate fertilization had no effect on silage protein at irrigated sites, but it did decrease protein in some of the dry land sites. This was due to a dilution effect caused by the yield increase in response to applied P and suggests that additional N would have been required to maintain the protein levels at the higher yield. BC

The authors are with Alberta Agriculture, Food and Rural Development. Dr. McKenzie is Soil Fertility Specialist, at Lethbridge, AB. Mr. Middleton is Agronomy Technologist at Lethbridge. Mr. Solberg is Research Agronomist at Edmonton. Ms. DeMulder is Agronomy Research Coordinator at Edmonton. Mr. Najda is Forage Crops Agronomist at Brooks.

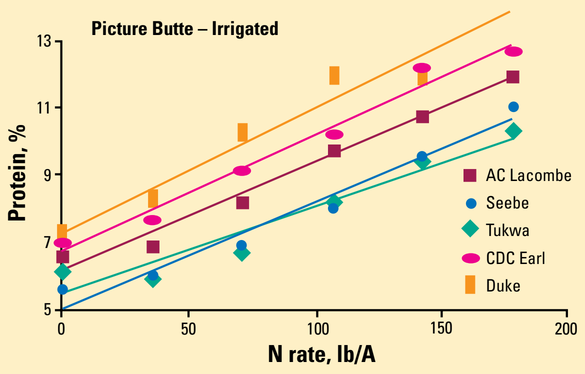

Figure 2. Applied N increases protein concentration of several irrigated barley varieties in Alberta.

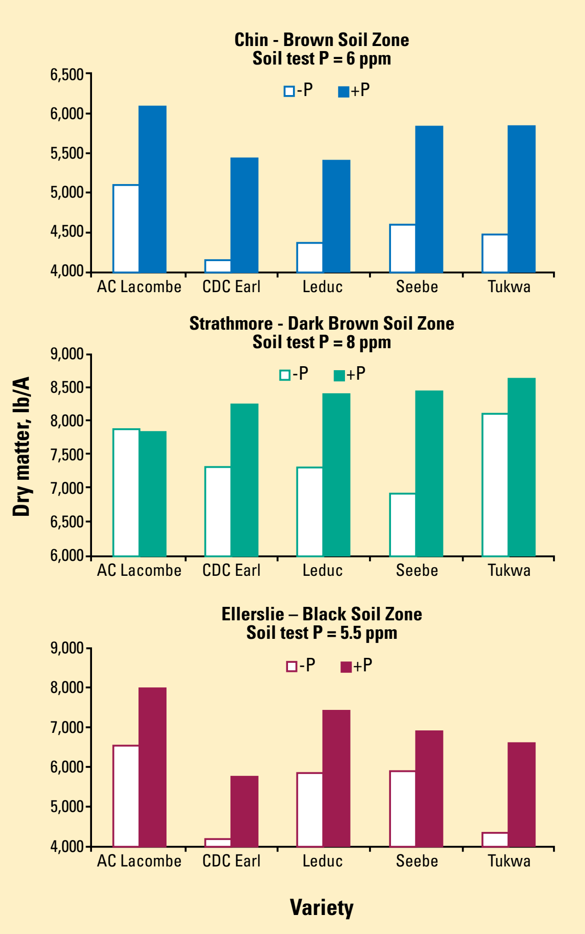

Figure 3. Dry matter silage responds to P fertilization at sites in the Brown, Dark Brown, and Black soil zones in Alberta.

Extending Phosphorus Fertilizer Benefits in Established Alfalfa

By J.W. Bauder, D.J. Sieler, Shaukat Mahmood, and J.S. Jacobsen

Effectiveness of phosphorus (P) fertilizer applications for alfalfa depends on several factors, including initial soil test P level, pH, and soil texture, method and rate of P application, health and vigor of the crop, and subsequent moisture conditions. Numerous studies have reported the effectiveness of surface broadcast applications of P to established alfalfa can be significantly limited on calcareous soils. Phosphorus, when applied to these soils, readily combines with free calcium (Ca) to form insoluble products.

Much of the soil on which alfalfa is planted in the semi-arid and arid regions of the world has relatively high concentrations of calcium carbonate ($CaCO_3$). Concentrations frequently range from a few percent (by weight) to as much as 8 to 10 percent or more. These concentrations are often synonymous with soil pH values greater than 8.0, fine textured soils, and $CaCO_3$-rich irrigation water. The fixation capacity of these soils significantly reduces the effectiveness of limited amounts of P fertilizer incorporated into the soil during seedbed preparation, thereby necessitating frequent annual applications.

In order to better understand the fixation process and the role of P incorporation into existing alfalfa stands, we conducted a 3-year study in southeast Montana. The objective of our investigation was to determine the residual effect or duration of the response of 3 to 5 year old stands of alfalfa to various rates and methods of P application. This study was initiated in September 1991, and continued through October 1994, at three field locations.

Treatments

Phosphorus was applied in October 1991 (fall treatments) and in March 1992 (spring treatments). We then compared yields over the next three growing seasons. The methods of P application included subsurface banding (knifing at a 3 to 4 in. depth) on 16 in. centers using a modified double-disk drill with fertilizer banding capabilities, surface broadcast application, and surface banding on 8 in. centers. A single rate of 300 lb of P_2O_5/A was used for all P treatments. Control treatments were a single knifing operation without any P fertilizer addition and a check treatment (no P, no stand disturbance). All treatments were replicated three times. Plots were harvested up to three times a year depending on the availability of irrigation water. Fields were harvested for hay (and data collected) when irrigation water was available to produce reasonable growth. When water was not available, usually toward mid- to late-season, the fields were managed as pasture (no data collected). Hay was harvested nine times over 3 years at the Griffin Ranch, two times over 2 years at the Jurica Ranch and four times over 3 years at the Gay Ranch. Soil characteristics are presented in **Table 1**.

Results

Table 2 contains a summary of the yield response (tons/A/harvest) to P over a 3-year period. We concluded that at all three sites, response to P additions was significant relative to the check treatment. Disturbing the soil by knifing the alfalfa stand without addition of P caused a slight decrease in yield at the Gay site and increases at the other two sites. Addition of P during the knifing operation more than compensated for yield reductions due to knifing at the Gay site. Differences between time of application (fall vs. spring) and among methods of application were generally small and inconsistent across sites. This may be due in part to the relatively high rate of P fertilizer used. Under the conditions of this research, surface application appears to be most economical due to the lower cost of application compared to knifing P into the soil.

TABLE 1. Soil characteristics at 3 study sites.

Location and soil depth, inches	pH	Available P, ppm[1]	Free lime, %	Soil texture
Griffin Ranch				
0-3	8.3	9.2	2.4	Coarse-loamy, mixed, fine sandy loam
3-6	8.3	3.0		
6-12	8.4	2.4		
Jurica Ranch				
0-3	8.3	11.5	3.6	Fine-loamy, mixed loam
3-6	8.3	3.2		
6-12	8.5	5.6		
Gay Ranch				
0-3	8.1	2.9	6.1	Fine, montmorillonitic silty clay
3-6	8.4	2.1		
6-12	8.4	1.0		

Available P was determined by Olsen's bicarbonate test.
Percent free lime determined for 0-6 inch depth. [1]ppm = parts per million

TABLE 2. Summary of alfalfa yields following three different methods of P application at 300 lb/A of P_2O_5.

	Griffin Ranch	Jurica Ranch	Gay Ranch	Average
Treatment	Avg. yield per harvest, t/A (12% moisture)			
Check	2.17	1.24	1.73	1.93
Fall application				
Knife (no P)	2.30	1.43	1.63	2.00
Knife	2.50	1.65	1.76	2.19
Surface band	2.49	1.57	1.95	2.23
Topdress	2.40	1.69	1.89	2.17
Spring application				
Knife (no P)	2.21	1.53	1.65	1.97
Knife	2.42	1.58	1.85	2.15
Surface band	2.36	1.50	2.05	2.16
Topdress	2.38	1.59	1.89	2.14
LSD (0.05)	0.12	0.09	0.09	0.09

Over the 3-year period, the total yield response across P treatments to 300 lb/A of P_2O_5 was 2.1, 0.7 and 0.9 tons/A for the Griffin, Jurica and Gay sites, respectively, on total yields up to 22.5, 3.3 and 8.2 tons/A (data not shown). These are relatively small responses that reflect lack of available water for hay production at the latter two sites. The yield increase necessary to pay the cost of the P fertilizer is about 0.8 tons/A (@$90/ton of hay and 25 cents/lb of P_2O_5). This does not factor in the cost of application or the additional pasture that may have been produced. Although responses at the Jurica and Gay Ranches are at about the breakeven point, hay responses in the third year were similar to the first 2 years, suggesting that there is sufficient residual P for continued yield responses in future years.

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TEXAS

Deep Phosphorus Banding in Winter Wheat – A Risk Management Tool for the Southern Great Plains

By Travis D. Miller

Rainfall in the Southern Great Plains may range from 10 to 50 inches per year, and distribution of that rainfall may place a wheat crop in jeopardy of injury from both flood and drought conditions in one growing season.

In this region, wheat is a dual purpose crop, with winter pasture and grain production both being of great importance to farmers and ranchers. It is estimated that Texas wheat growers graze more than 70 per cent of the crop, and that 40 to 45 per cent is grazed the entire season with no grain harvested. Therefore, fertilizer management to enhance early forage production is of near equal importance to practices which optimize grain yield.

> Reevaluating phosphorus (P) application technology may be one of the more important risk management tools that can be used by wheat farmers who rely on income from grazing and grain production in the Southern Great Plains.

Late August through early October is typically a high rainfall period, with accumulations of 3 to 4 inches per month. The October through March period tends to be a very dry time of the year, with normal averages below one inch per month, resulting in a deficit moisture condition. Wheat is planted early to optimize vegetative growth for winter grazing. This rapid early growth tends to deplete surface moisture. If we look at mobile fertilizer elements such as nitrogen (N), this does not pose a problem as active roots in the lower soil profile continue to supply the crop with N. With P, we begin to quickly see a yield limiting situation with conventional fertilizer application techniques.

Phosphorus deficiency caused by reduced tillage and surface application of P results from stratification of nutrients in the soil. When the surface 2 or 3 inches are moist, and wheat roots are active, this P is taken up and used by the crop to good effect. However,

TABLE 1. Response of wheat forage to fertilizer placement, Texas Rolling Plains.

		Forage yield[1], lb/A			
Location	**Year**	**Deep P+N**	**Surface P+N**	**N only**	**Check**
Runnels	1988	2,583a	1,595b	1,482b	—
Wichita	1995	2,357a	1,238b	1,257b	1,199b
Baylor	1994	2,552a	1,248b	1,568b	—
Baylor	1995	4,295a	3,757b	3,615b	3,607b
Abilene	1995	3,898b	4,770a	2,200c	—
Abilene	1997	580a	483a	477a	259b
Young	1997	1,050a	749bc	935b	598c
Wichita	1997	1,003a	929a	912a	—
Average		2,290	1,856	1,556	

[1]Yields in the same row followed by the same letter are not different according to LSD test at 95% level of confidence.

as the crop reaches deficit moisture conditions in the fall and winter, this P-enriched zone is too dry for active root uptake of fertilizer. Although the wheat continues to grow and make good use of water from lower in the soil profile, the crop is nutrient-deficient with respect to immobile nutrients concentrated in the surface 2 or 3 inches of soil.

Based upon studies reported in this article and numerous others, P is of great importance in establishing tillers, a deep, massive root system, and fall vegetative growth. These studies clearly indicate that when lack of fall moisture limits activity of roots near the surface, forage yields are greatly increased by deep P application. It is theorized that these dramatic responses in forage growth are related to better moisture availability associated with the location of the fertilizer band in the soil profile and the subsequent increased availability of fertilizer P over a greater percentage of the growing season. It is clear that lower wheat forage yields can be largely attributed to P deficiency, particularly early season P deficiency. Further, conventional P incorporation technology results in fertilizer which is not readily available during the dry fall weather common to much of the Southern Great Plains.

Beef cattle production is the largest agricultural enterprise in the Southern Great Plains. The potential for enhanced forage yields and the resultant increase carrying capacity under drought conditions have very large implications. Drought and the fear of drought weigh heavily in the management plans of most farmers and ranchers in this production region. In good (wet) conditions, properly managed wheat pastures can generate 3,000 to 4,500 lb/A dry weight forage. When judiciously grazed, it can result in 200 to 400 lb/A weight gain in light weight stocker calves. In dry years, forage yield might be realistically reduced to 750 to 1,500 lb of dry matter. In fields such as these, farmers may deem forage supplies inadequate to turn cattle into the fields. As wheat pasture is commonly leased on a gain basis, and $35/cwt gain is a widely used contract price, gross income from wheat pasture leases can vary from zero to $150/A.

Approximately 10 million acres of wheat are grazed annually in this production region. The economic potential for a system to improve yields in the high risk (dry) years is enormous with respect to farmers, ranchers, and the agricultural industry as a whole. Those years with zero return for fertilizer dollars invested are a great deterrent to further investment in fertilizer by farmers and certainly a drain on the financial bottom line. This article highlights research evaluating the effect of P fertility and its placement on wheat forage and grain yields. The results clearly indicate that P fertilizer is a key component of forage and grain yields in dry years in wheat production systems. Further, wheat farmers are at less risk of a crop failure due to drought when P is deep banded preplant than with conventional fertilizer application techniques or when no P fertilizer is applied.

Materials and Methods

In each trial, plots were planted early relative to the optimum date for grain production in winter wheat. This is common in the wheat-stocker cattle production system, as early heat units drive the forage production upon which the stocker cattle component of the system depends. The fertilizer applied was fluid ammonium polyphosphate (10-34-0) in all trials except those at Abilene. Trials at Abilene used 11-52-0 (MAP) banded at the 6-inch depth with an air seeder and compared to the same rate surface applied with an air boom and incorporated prior to planting. The Abilene trials used anhydrous ammonia (NH_3) at 80 lb N/A, while urea ammonium nitrate (UAN) was used on the other trials at a rate of 50 lb N/A. In other trials, banded applications were preplant injected on 10-inch centers at a depth of 8 inches at a rate of 50 lb N/A. Surface incorporated treatments were dribbled on the surface and then incorporated either with a disk or field cultivator. Rate of application was 40 lb/A P_2O_5, with the exception of the Abilene site where the rate was 50 lb/A. Wheat was planted on dates from mid-September to early October with a plot drill on 10-inch centers. Forage was hand clipped using a small frame, oven dried, and weighed. Grain yield was determined by using a Hege

TABLE 2. Response of wheat grain yield to fertilizer placement, Texas Rolling Plains.

		Forage yield[1], lb/A			
Location	**Year**	**Deep P+N**	**Surface P+N**	**N only**	**Check**
Runnels	1988	31.0a	25.8b	20.8c	—
Baylor	1994	46.0a	47.0a	35.0b	—
Baylor	1995	41.4a	39.2a	39.1a	27.9a
Wichita	1995	16.4a	5.1b	4.8b	3.5b
Abilene	1995	34.0b	48.5a	19.5c	—
Abilene	1996	22.0a	13.2b	12.2b	7.7d
Average		31.8	29.8	21.9	

[1] Yields in the same row followed by the same letter are not different according to LSD test at 95% level of confidence.

plot combine. Plot design was a randomized complete block with either 3 or 4 replications.

Results and Discussion

In these trials, forage dry matter yield response was greatest with deep banded P relative to surface incorporated P or the untreated check in dry years (**Table 1**). In five of eight site-year comparisons in the Texas Rolling Plains, deep banded P resulted in forage yields 50 percent greater (850 lb/A forage) than wheat treated with the same rate of surface incorporated P and 45 percent greater (796 lb/A forage) than wheat treated with the same rate of N but no P fertilizer. In four of the five sites, fall weather was abnormally dry while at the fifth site, weather was average. Two clear effects were noted: The first is that P placement significantly improved forage yield; the second is that P use efficiency with respect to forage yield with surface incorporated P in dry fall weather was nil.

In six trials where valid comparisons of grain yield were made between P placement techniques, three yielded significantly higher with deep placed P, with the yield average of deep banded P being 8.4 and 10.5 bu/A greater than the surface incorporated treatment and the untreated check, respectively (**Table 2**). This represents a yield increase of 57 and 83 percent under very dry growing conditions. In two trials, there was no difference between P placement techniques with respect to grain yield. In one trial during a very wet growing season, wheat fertilized with the surface incorporated P yielded more than the deep, banded P treatment. Averaged over six sites, deep banded P resulted in grain yields of 2.0 and 9.9 bu/A greater than the surface incorporated P and untreated check, respectively. In two sites (Wichita 1995 and Abilene 1996) where drought drastically limited grain yield, no response was obtained to N fertilizer alone or N fertilizer with surface incorporated P. Significant yield response was obtained with N and deep banded P.

Conclusions

There has been a widespread perception among wheat farmers that fertilizer applied in drought conditions is risky, and that fertilizer dollars are better spent elsewhere when the weather does not cooperate. This research proves the perception is correct and at the same time highly in error. When P fertilizer was applied in the traditional manner by surface application followed by incorporation, no effect was visible with respect to forage yield in average to dry fall weather, and in years where dry weather continued through grain fill, little effect was noted in grain yield. In two trials, neither grain nor forage yield was affected by P or N fertilizer when surface applied and shallow incorporated. However, in these same trials, significant and economic yield responses were observed in both grain and forage yield when P fertilizer was deep banded.

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OKLAHOMA

Remediation of Heavy Metal-Contaminated Soil Using Rock Phosphate

By N.T. Basta and R. Gradwohl

Research over the past few decades has focused on the use of "chemical immobilization" products to chemically alter soil heavy metals to less soluble and less bioavailable forms. Organic amendments (municipal biosolids, composts, manures), alkaline materials (limestone, cement kiln dust, fly ash), and phosphate amendments [rock phosphate (RP), commercial fertilizers, phosphoric acid] have been studied for remediation of heavy metal-contaminated soil.

Extensive lead (Pb) and zinc (Zn) ore mining and smelting have resulted in contamination of soil that poses risk to human and ecological health. Many reclamation methods used for these sites are lengthy and expensive and may not restore soil productivity. Soil heavy-metal environmental risk to humans is related to bioavailability. Assimilation pathways include the ingestion of plant material grown in (food chain), or the direct ingestion (oral bioavailability) of, contaminated soil.

Objectives of this work were to evaluate (1) the ability of RP treatment to reduce plant and oral bioavailability of cadmium (Cd), Pb and Zn, and (2) the long-term stability of phosphate-treated soil.

Plant and Oral Bioavailability

Soil (loam, pH 6.4) contaminated by Zn and Pb milling and smelting was mixed with North Carolina RP at 1 lb RP per 10 lb soil. Triplicate treated soils and an unamended control were wet to 25 percent moisture and incubated at 80°F for 90 days. During the incubation, water was added to maintain moisture, and the soils were mixed weekly. After incubation, lettuce was grown under controlled conditions until maturity in 6-inch pots containing soil. Lettuce was harvested and analyzed for Cd, Pb and Zn. Oral bioavailability of heavy metals was estimated by the Physiologically Based Extraction Test (PBET). This test simulates human gastrointestinal chemistry. The PBET procedure has two extraction phases: gastric and intestinal. Heavy metal dissolved by the PBET method was used to estimate oral bioavailability.

Lettuce did not grow on the control soil because the soil had greater than 0.01 lb plant available Zn/10 lb of soil...extracted with 0.01 M calcium nitrate [$Ca(NO_3)_2$] ...resulting in Zn phytotoxicity. Therefore, it is not possible to determine reductions in heavy metal content of lettuce due to RP. Treatment of contaminated soil with RP reduced plant available Pb, Cd and Zn

Lettuce grown in control and treated contaminated soil. Photo taken at time of harvest. Treatments are lime-stabilized municipal biosolid (LS), a blend of municipal biosolids and alkaline admixtures (NV), rock phosphate (PO_4), and an anaerobically digested municipal biosolid (SS).

TABLE 1. Plant and oral bioavailability of heavy metals in RP-treated contaminated soil.

Heavy metal	Plant available, ppm[1] soil		Oral bioavailability: Gastric phase, ppm soil		Oral bioavailability: Intestinal phase, ppm soil	
	Control	RP	Control	RP	Control	RP
Pb	0.54	0.37	7.1	5.5	1.8	0.2
Cd	186	98	6.4	5.3	4.0	1.0
Zn	1,090	740	266	250	163	38.1

[1] ppm = parts per million

(**Table 1**). Reduction of plant available Zn by RP and several other treatments allowed growth of lettuce on treated soil (see photo on previous page). The RP treatment resulted in small, but not significant ($P<0.05$), reductions in heavy metal oral bioavailability measured by the PBET gastric phase (**Table 1**). The intestinal-phase concentrations of Cd, Pb and Zn were lower than their respective gastric-phase concentrations. Rock phosphate treatment reduced intestinal-phase Pb by 90 percent, Cd by 75 percent, and Zn by 77 percent (**Table 1**).

The PBET results do not represent actual amounts of bioavailable metal absorbed into the body. However, they may represent metal fractions potentially bioavailable for absorption. Our results show RP amendments are more efficient in reducing soluble metals in the intestinal phase. However, the PBET method has never been evaluated for treated contaminated media. Therefore, we do not know if the gastric or intestinal phase is the best predictor of bioavailability. Although metal absorption occurs in the intestine, the higher gastric phase metal concentrations may be used as a conservative worse-case scenario. The actual oral bioavailability of these metals may occur at values between those predicted by the gastric and intestinal phases.

Long-Term Chemical Stability of Treated Soils

Long-term stability of chemical immobilization of heavy metals using RP methods was examined by acidifying soils with nitric acid to target pH levels of 6, 5.5 and 4 to mimic natural soil acidification. Changes in readily available Cd, Pb and Zn were determined by extraction with 0.01 M $Ca(NO_3)_2$. Acidification resulted in an increase of available Cd, Pb, and Zn in the control soil (**Table 2**).

In general, soil treatment with RP reduced available heavy metal. Soil acidification of RP-treated soil decreased Pb availability, unlike the control. Apparently soil acidification dissolved the carbonated apatite RP which resulted in formation of insoluble Pb phosphate minerals. Results from other studies suggest the formation of extremely stable pyromorphites is responsible for Pb immobilization in soil systems as well as apatite ion exchange, adsorption, and coprecipitation. Unlike Pb, Cd and Zn availability increased with soil acidification. However, increases of heavy metal availability in RP-treated soil was smaller than in control soils.

Summary

Treatment of smelter-contaminated soil with RP reduced Zn phytotoxicity and

TABLE 2. Changes in heavy metal availability due to soil acidification.

Heavy metal	Soil pH	Available metal, ppm soil: Control	Available metal, ppm soil: RP
Pb	6.5 (initial)	6.2	6.9
	6.0	17	2.4
	5.5	32	4.0
	4.0	55	1.5
Cd	6.5 (initial)	194	96
	6.0	256	129
	5.5	263	150
	4.0	287	254
Zn	6.5 (initial)	1,300	784
	6.0	3,130	3,530
	5.5	9,630	5,990
	4.0	12,040	7,760

In Memory of Santford W. Martin, 1922-1998

Santford W. Martin

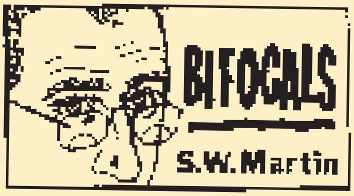
Mr. Santford W. Martin, who served as Editor for PPI and its forerunner organizations for more than 30 years, passed away September 18, 1998. Mr. Martin, who was age 76 at the time of his death, began his career with the Institute in 1957.

A native of Winston-Salem, North Carolina, he served 3 years in the military during 1943 to 1946. Mr. Martin was a graduate of Wake Forest University with B.A. (1947) and M.A. (1948) degrees, majoring in English-Journalism.

With a widely recognized talent for improving the readability of agronomic information, Mr. Martin edited *Better Crops with Plant Food* magazine and other Institute publications. He also wrote a popular column called "Bifocals," which appeared in the magazine until 1980.

Before joining the Institute staff, Mr. Martin was Publications Editor for the Development Program of North Carolina State College. Earlier, he was Director of Publicity and Department Head at Gardner-Webb College, and also served as Director of Information for the North Carolina Alcoholic Rehabilitation Program.

"Santford Martin was a talented and respected man of highest integrity. He will be dearly missed by his family and all who knew him. There are many people who never met Santford, but yet thought of him as a friend because of his writing. He was a creative and productive individual and inspired many others to higher standards through his dedication and example," said Dr. David W. Dibb, PPI President.



reduced plant available Cd, Zn and Pb. Oral bioavailability of Pb, Cd and Zn was also reduced by RP treatment, but the extent of reduction is uncertain. Small reductions in oral bioavailability were measured by the PBET gastric phase, but large reductions were obtained by the PBET intestinal phase. Lead immobilized by RP is very stable to soil acidification. In fact, acidification increases the amount of Pb immobilized. Increased available Cd and Zn suggests some of the fraction immobilized by RP may not be stable to soil acidification. However, available Cd and Zn in acidified RP-treated soil was less than that in the acidified control soil. Rock phosphate may serve as an inexpensive alternative method for remediation of smelter contaminated soil.

Research investigating use of RP and other phosphate sources (commercial fertilizer, phosphoric acid) is in progress at several universities (Florida, Kansas State, University of Missouri, Ohio State, Oklahoma State), the U.S. Environmental Protection Agency, and private industry.

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"Wicked" Youth?

The news media extol the evils of today's youth. We are distressed. Just listen to this: "The sins of youth include too much luxury, contempt for authority, over-indulgence of self...they contradict their parents and tyrannize their teachers."

Sound familiar? Those words came from a speech made about 400 years before Christ – by Aristotle!

I enjoy working with young people. Most are serious, caring, inquisitive, challenging, and anxious to improve things. As a whole, they are better behaved than was my generation.

A visit to the State Science Fair was inspiring – 623 exhibits, all well done. These were the division winners from thousands of entries. Categories included physics, chemistry, biology, engineering, botany, and more. Each project presented the hypothesis, research, result, and conclusion.

Many projects were agriculturally related. This is to be expected since agricultural science is a composite of the basic sciences. Environmental protection, crop and soil science, pesticides, soil erosion – all were subjects of excellent projects.

Emphasis on youth's problems can blind us to the goodness and potential of most of them. Let's hear more about these promising young people who are exploring the Earth's secrets. They are the ones who will conserve the world's resources and feed its people. I left the fair with unbridled optimism.

J. Fielding Reed

BETTER
CROPS
WITH PLANT FOOD

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