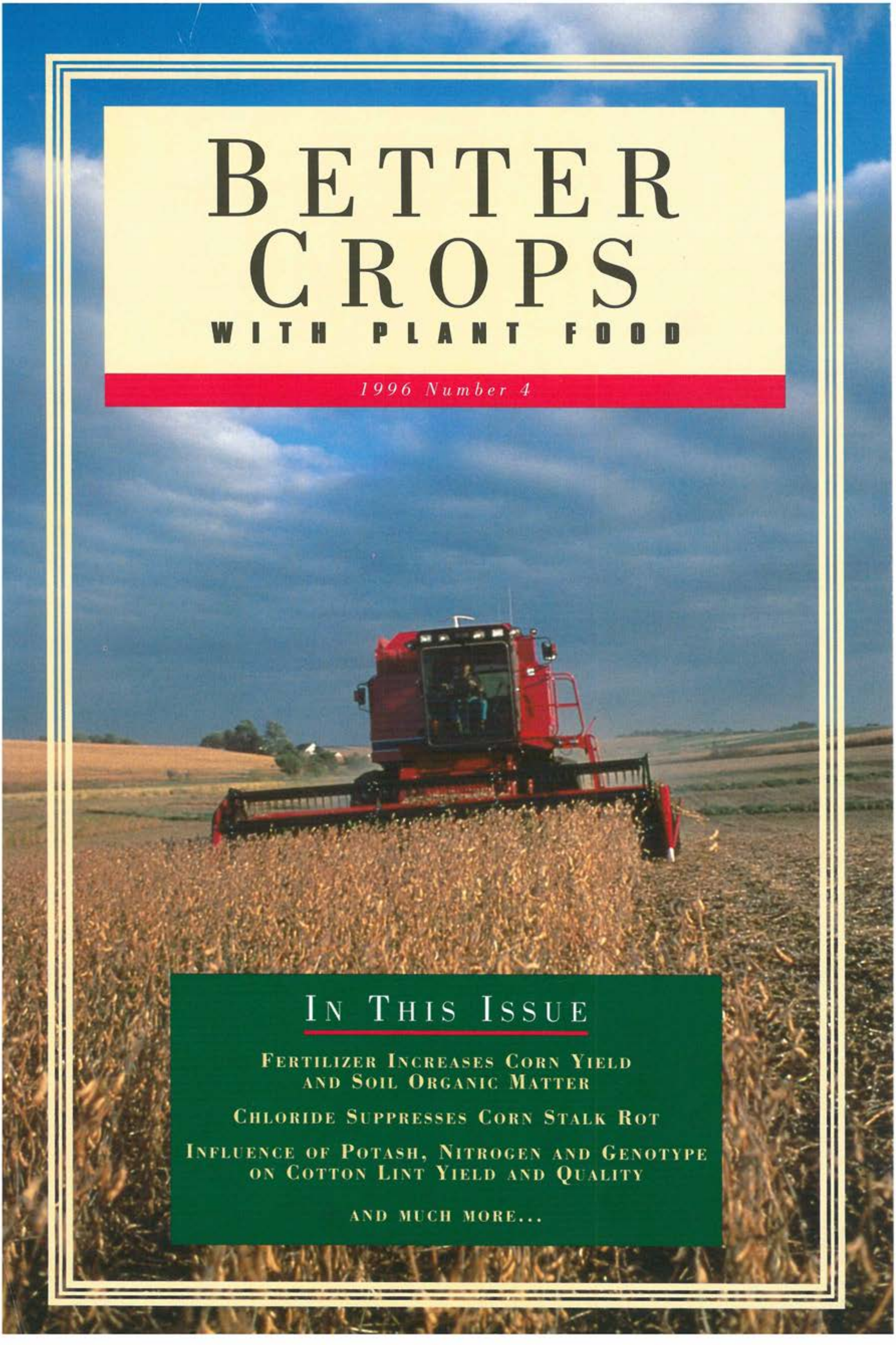
BETTER CROPS WITH PLANT FOOD

1996 Number 4



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AND MUCH MORE...

BETTER CROPS WITH PLANT FOOD

Vol. LXXX (80) 1996, No. 4

Our Cover: Soybean harvest in the Midwest.

Design: DesignRT

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ONTARIO

Fertilizer Increases Corn Yield and Soil Organic Matter

By E.G. Gregorich and C.F. Drury

Soil and crop management practices, including fertilization and crop rotation, affect both crop productivity and soil characteristics. For example, at the Rothamsted Experimental Farm in the United Kingdom, monoculture wheat and barley yields have been sustained for 150 years with annual application of organic or inorganic fertilizers, and soil organic matter content of the soil increased under inorganic fertilization.

An Ontario study shows that fertilization and crop rotation not only improve corn yields, but also increase soil organic matter levels under continuous corn with fertilization.

A long-term experiment started in 1959 in southwestern Ontario, Canada, provided the opportunity to study the effects of fertilization, crop rotation, and weather on corn yields, as well as the effects of fertilization on organic matter levels in soil under continuous corn.

Corn Yields

The use of mineral fertilizers in North American crop production increased steadily from 1950 up to the early 1980s. Many studies have demonstrated crop yield increases in response to fertilization, particularly when adequate water is available. Crop rotations have been used to increase soil organic matter, reduce soil erosion, lower the risk of insects and diseases, and, when legumes are included, to supply nitrogen (N) to the soil for the following crop.

We examined the yields of corn grown continuously or in rotation (corn-oats-alfalfa-alfalfa) with and without fertilization (115-60-30 lb/A N-P_2O_5-K_2O) for 35 years. As shown in **Figure 1**, the fertilized rotation corn treatment produced the highest average yields (123 bu/A), followed by the fertilized continuous-corn treatment (96 bu/A). Fertilization increased yields by 279 percent for continuous corn and by 70 percent for rotation corn. Yield fluctuations were largest for unfertilized continuous corn and

FERTILIZED continuous corn plot at left is contrasted with fertilized rotation corn plot at right above.

NON-FERTILIZED continuous corn plot shown at left above shows very limited growth compared to non-fertilized rotation plot at right.

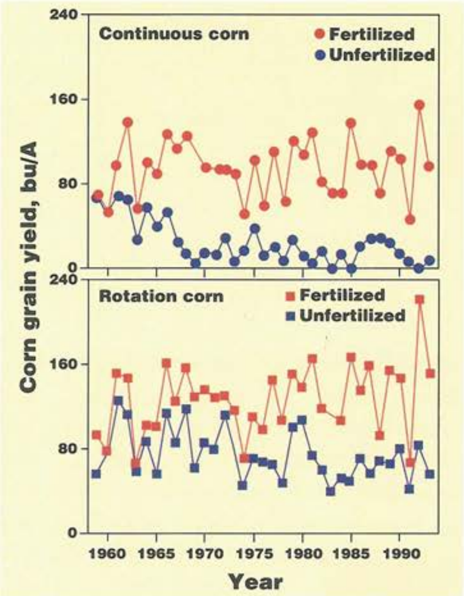

Figure 1. Fertilized-rotation corn produced highest yields over a 35-year period (Ontario).

smallest for fertilized rotation corn. Yields increased over time for the fertilized rotation corn, remained fairly steady for the fertilized continuous corn, and decreased over time with both unfertilized treatments. Growing season precipitation was the only weather variable tested that related significantly to crop yield; July precipitation was proportional to crop yield for both fertilized treatments. However, weather variability had little effect on yields of unfertilized corn.

Crop rotation and fertilization have dramatically changed soil properties such as soil structure and organic matter. These changes have affected soil tilth, water drainage and moisture retention, bulk density, and soil fertility. During the period of this long-term study, crop varieties have also improved. Therefore, yield averages from 1989 to 1993 are useful to assess the long-term effects of these soil and crop management practices on the present day productivity of the soil (**Table 1**).

Soil Organic Matter

The amount of organic matter in soil is related to the amount of plant residues returned to the soil and the rate at which those residues decompose. Fertilization affects the vigor and yield of a crop, thus affecting the amount of crop residues left after harvest and, in turn, the amount of soil organic matter generated by these residues. We looked at the effects of fertilization on the turnover and storage of carbon (C) derived from corn residue in a medium-textured soil that had been under continuous corn for 32 years. Using a ^{13}C isotopic technique, we were able to differentiate between soil organic matter derived from corn, a C_4 plant, and soil organic matter derived from the C_3 plants that grew prior to corn cultivation.

We found that soil under continuous corn, fertilized for more than 30 years, had greater amounts of soil C than systems that were unfertilized (**Table 2**). The difference between the amount of C present in the fertilized and unfertilized systems was attributed to the amount derived from corn (C_4-C). About 22 percent of the organic C was derived from corn in the fertilized soil, whereas only 14 percent of the organic C was derived from corn in the unfertilized soil. The amount of C derived from plants present before the experiment

TABLE 1. Average corn grain yields from 1989 to 1993 and organic matter levels in soils under different management practices.

Management practice	Fertilization $N-P_2O_5-K_2O$, lb/A	Grain yield, bu/A	Organic matter, %
Continuous corn	115-60-30	104	3.5
Continuous corn	0-0-0	12	3.1
Rotation corn	115-60-30	145	4.3
Rotation corn	0-0-0	65	3.2

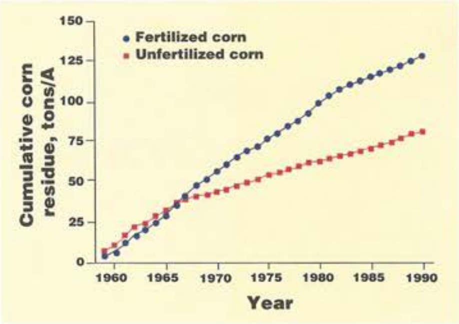

Figure 2. Amount of corn residue returned was estimated at 128 tons/A for the fertilized system and 71 tons/A for the unfertilized treatment.

was initiated (C_3-C) was the same in fertilized and unfertilized soils under continuous corn. This indicated that long-term fertilization did not enhance the decomposition of the native soil organic matter.

The isotopic technique, along with estimates of plant biomass from the annual yield data (**Figure 2**), allowed us to calculate a C budget for the soils. Over the period of the study the total amount of corn residue returned was estimated at 128 tons/A (51 tons/A of C) for the fertilized system and 71 tons/A (29 tons/A of C) for the unfertilized system. The difference between the amount of C returned to the soil (estimated from yields) and the amount remaining in soil (estimated using the isotopic technique) shows that about 80 percent of the C from corn is decomposed and lost from the soil regardless of whether the crop had been fertilized.

We separated the floatable organic matter, called the light fraction, in order to evaluate the effects of fertilization on easily decomposable organic matter that would be a short-term source of nutrients. Between 40 and 70 percent of the light fraction organic matter in the surface 4 inches of both soils was derived from corn residues. However, there was more than twice as much light-fraction C in the fertilized soil as in the unfertilized. This difference was accounted for by the greater amount of C derived from corn residues in the fertilized system.

Conclusions

We concluded from this study that adequate fertilization improves corn yields, and that growing corn in rotation enhances yields further. Without adequate fertilization, crop yields are depressed even when other environmental factors, such as precipitation, are ideal. Yields of corn grown continuously without fertilization decline dramatically over time.

The results of this study also indicate that adequate fertilization contributes to the build-up of organic matter in soil and that fertilization does not significantly alter the turnover of native soil organic matter. BC

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TABLE 2. Amounts of organic C, corn-derived C, and native C in fertilized and unfertilized corn soils.

$N-P_2O_5-K_2O$, lb/A	Total carbon	Corn-derived carbon	Native carbon
		tons/A	
115-60-30	40	9	31
0-0-0	36	5	31

Influence of Potash, Nitrogen and Genotype on Cotton Lint Yield and Quality

By W.T. Pettigrew, J.J. Heitholt and W.R. Meredith, Jr.

The development of mid- to late-season K deficiency in cotton has become commonplace throughout U.S. cotton producing regions. This study was conducted at Stoneville, Mississippi, on a fine sandy loam. The objectives were to determine if genotypic lint yield and fiber quality varied in response to different levels of K fertilization, and if the lint yield response to N fertilization was different at varying soil K levels. Eight cotton genotypes were studied (DES 119, DPL 5415, HS 26, MD-51-NE, Pee Dee 3, Stoneville 453, Stoneville 825, and Stoneville LA887. The N rates were: (1) a preplant application of 100 lb N/A, and (2) 100 lb N/A applied preplant plus a sidedress application of 34 lb N/A at layby. Potassium at 120 lb K_2O/A was surface applied and compared to a no K control. Soil K levels, 0 to 6 inches, were 211 lb K/A for the zero K_2O rate and 288 lb K/A for the 120 lb K_2O/A treatment.

A USDA-ARS study evaluated the effects of potassium (K), nitrogen (N) and genotypes on cotton lint yields and fiber qualities. Potassium deficiency reduced lint yield, boll mass, lint percentage, seed mass, and some fiber quality traits. Varying the N rate did not affect these traits. Adapted genotypes did not exhibit a differential response to K.

Results

Potassium deficiency associated with the zero K_2O treatment reduced lint yield 9 percent, boll mass 7 percent, lint percentage 2 percent, and seed mass 4 percent (**Table 1**). Lint yield reduction, caused by the K deficiency, was attributed to coinciding reductions in the yield components: boll mass, lint percentage, and seed mass. Many fiber quality properties were altered by K deficiency, including fiber traits associated with fiber secondary wall thickening (micronaire and fiber maturity). Averaged across genotypes, K deficiency reduced fiber elongation by 3 percent, 50 percent span length by 1 percent, uniformity ratio by 1 percent, micronaire by 10 percent, fiber maturity by 5 percent, and fiber perimeter by 1 percent (**Table 2**).

Fiber strength in this study was not significantly affected by K fertilization, although others have reported strength reductions caused by K deficiency. It may be that K has only an indirect effect on

TABLE 1. Effects of K on cotton yield and yield components (two-year average across N rates).

K_2O rate, lb/A	Lint yield, lb/A	Boll mass, g/boll	Lint, %	Seed mass, mg/seed
0	1,061	4.1	38.6	90
120	1,169	4.4	39.3	94
LSD 0.05	31	0.1	0.3	2
Difference	9%	7%	2%	4%

TABLE 2. Effects of K on cotton fiber quality measurements (two-year average).

K_2O rate, lb/A	Strength,[1] kN m/kg	Elongation, %	Span 2.5%	Length 50%	MIC	Maturity, %	Perimeter, um	Uniformity ratio
			.... cm	....				
0	207	7.97	2.82	1.35	3.7	74.1	49.1	48.0
120	203	8.25	2.82	1.37	4.1	78.3	49.4	48.7
LSD 0.05	NS	0.25	NS	0.01	0.1	1.6	0.1	0.4
Difference	0%	3%	0%	1%	10%	5%	1%	1%

[1]Strength was determined by stelometer and not by HVI. To convert to g/tex, divide the value by 10 and then multiply by 1.02.

fiber strength. This indirect effect may have more to do with the early termination of reproductive growth caused by K deficiency and with the environmental conditions during this shortened window of reproductive growth than with the actual K level.

The 100 lb N/A rate was determined to be sufficient for the growing conditions of this study. Neither lint yield nor any of the components of yield were altered by the sidedress application of an additional 34 lb/A of N, as shown in **Table 3**. However, there was a tendency for the high N treatment to have a negative impact on lint yield and lint percentage when coupled with the zero K_2O treatment. Varying N rates did not affect any of the fiber traits.

Genotypes varied only slightly in their response to K fertilization. Adapted, normally high-yielding genotypes outyielded unadapted or poor yielding ones, regardless of the K level or maturity.

Summary

To assure that K does not limit cotton lint yields, growers should monitor K needs with soil testing and apply recommended K fertilizer rates to keep soil K levels adequate. This practice should produce profitable cotton yields with acceptable fiber qualities. BC

Drs. Pettigrew, Heitholt, and Meredith are with USDA-ARS, Cotton Physiology and Genetics Research Unit, Stoneville, MS 38776.

TABLE 3. Effects of N and K fertilization on cotton yield and yield components (two-year average).

N rate, lb/A	K_2O rate, lb/A	Lint yield, lb/A	Boll mass, g/boll	Lint, %	Seed mass, mg/seed
100	0	1,082	4.16	38.9	90
	120	1,165	4.32	39.2	93
134	0	1,047	4.10	38.4	89
	120	1,178	4.40	39.4	95
LSD 0.05[1]		38	NS	0.3	NS
	LSD 0.10[2]	30	NS	0.4	NS

[1]LSD within N values are for comparison of K rates within a given N rate level.
[2]LSD within K values are for comparison of N rates within a given K rate level.

Grassed Filter Strips Can Reduce Losses of Nitrogen and Phosphorus in Runoff

By D.R. Edwards, P.A. Moore, Jr. and T.C. Daniel

Many studies have been conducted over the past three decades to learn the quantity of nutrients lost in runoff, what variables affect these losses, and how nutrient loss can be minimized. Most studies have focused on row crops, which are managed intensively in comparison to forage crops. We have investigated similar questions over the past seven years for pasture systems, because they are the dominant agricultural activity in some regions, especially in areas unsuitable for row crop production. When nutrients are applied as manure or fertilizer, pasture systems should also be managed so that nutrient runoff is minimized.

> Farmers have for many years used various management techniques to minimize runoff losses of nutrients. In the past, this was primarily because losses represented wasted time, effort and money. With increased awareness of the potential environmental impacts of nutrient losses, these management techniques are now considered an essential element of good stewardship of natural resources.

Preliminary Studies

The goal of our initial field experiments was to determine how nutrient loss in runoff was related to application rate and storm severity. We did this work on 5 ft. by 20 ft. plots with fescue established on a silt loam soil. Animal manures (broiler litter, poultry manure and swine manure) were applied (at 0.5, 1, and 2 times the recommended rates) to moist soil. Simulated rainfall was applied the following day at 2 and 4 inches/hour until 30 minutes of runoff had occurred. Runoff losses increased with application rate and storm severity, as expected. Nutrient losses amounted to reasonably low (less than 5 percent) proportions of the amounts applied, even though the experimental conditions were severe.

In follow-up work the same experimental set-up was used to compare poultry litter, swine manure, poultry manure, and inorganic fertilizer in terms of nutrient loss and to learn how nutrient loss varied with the number of runoff events following application. Runoff loss of total nitrogen (N) was generally the same for all sources, but more phosphorus (P) was lost from the plots that received inorganic fertilizer than with those treated with animal manure. We also found that considerably more fertilizer was lost in the first simulated storm following application than in succeeding storms (**Figure 1**), and that runoff reached background levels of N and P after 2 or 3 simulated storms. Our chemical analyses also showed that most nutrient loss (especially for inorganic fertilizer) consisted of soluble forms, as opposed to particulate forms. This indicates that techniques that reduce erosion would

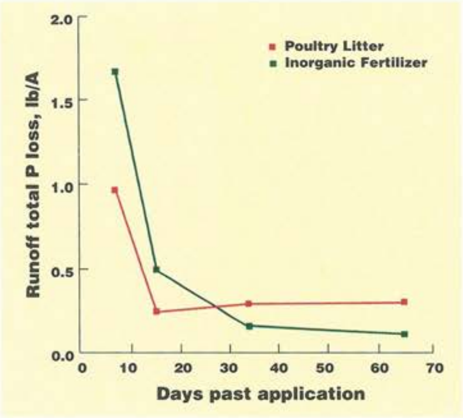

Figure 1. Relationship between time past application and runoff P loss for inorganic fertilizer (13-13-13) and poultry litter. Total N applied was 244 lb/A, with the balance of N from ammonium nitrate in the fertilizer treatment. Total P_2O_5 rate was 230 lb/A.

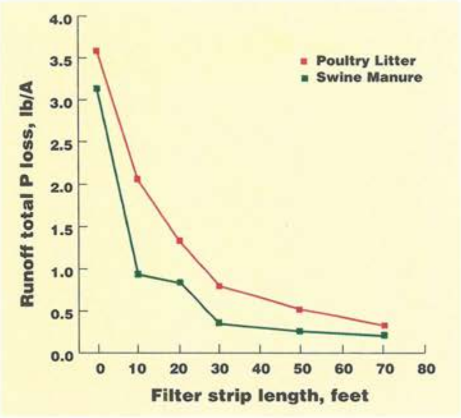

Figure 2. Effect of grassed filter strip length on runoff P loss for swine manure and poultry litter. Total N applied was 208 and 227 lb/A, and total P_2O_5 applied was 230 and 360 lb/A, for the poultry litter and swine manure, respectively.

have little or no impact on reducing nutrient losses under our conditions.

It is tempting to dismiss runoff losses of a few pounds per acre of N and P as insignificant from the standpoint of environmental impacts. While these small losses might be of little or no agronomic significance, aquatic systems can be considerably more sensitive to relatively small nutrient loadings than row crop and pasture systems. In other words, seemingly small amounts of N and/or P can cause undesirable growth of algae and aquatic weeds in ponds or lakes, even though they might have no noticeable impact if applied to pasture or row crops. Therefore, we began work to study management techniques that could reduce nutrient runoff losses to levels even lower than what we had observed.

Grassed Filter Strip Studies

In 1993, we began to examine how effective grassed filter strips (GFS) were in terms of removing nutrients in runoff from pasture. Grassed filter strips (also known as buffer zones and buffer strips) are simply grassed areas installed downslope of fertilized areas to filter and purify entering runoff as it flows across the filter. Other scientists had studied GFS previously, finding that they could be quite effective (better than 95 percent) in removing sediment and nutrients, but relatively little work has been done to establish their effectiveness for pastures. Our experimental set-up was similar to that described earlier, but we used 80 ft. plot lengths instead of 20 ft. We applied poultry litter and swine manure to the upper 10 ft. of the plots having a 3 percent slope, letting the remaining 70 ft. act as a GFS, and analyzed runoff samples collected at various distances down the GFS. Our results were similar to those from other studies, showing that 90 percent or more of the incoming N and P was removed by the GFS (**Figure 2**). There was generally

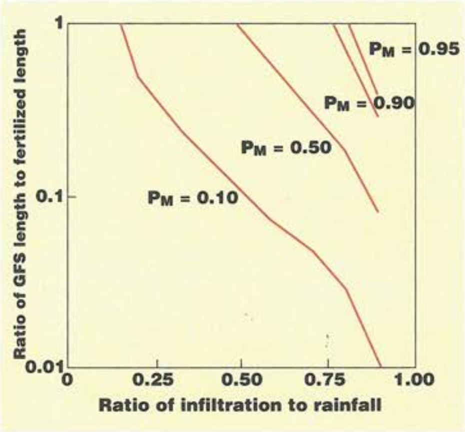

Figure 3. Required ratio of grassed filter length to fertilized field length as a function of the ratio of infiltration to rainfall and the desired reduction in soluble N and P loss (P_M).

no additional removal beyond a GFS length of 30 ft.

We followed the preliminary GFS work with a study to learn how filter effectiveness varied depending on the length of fertilized runoff source. In this work, we applied poultry litter to 20, 40 and 60 ft. of the 80 ft. long plots, having a 3 percent slope and allowed the remaining plot lengths to serve as GFS. Even for the longest fertilized length, small GFS lengths were effective (20 to 40 percent) in removing incoming N and P. However, the effectiveness of a particular GFS length decreased with increasing length of the contributing fertilized area, as expected. This is because under our conditions, the GFS removed N and P primarily through infiltration. Water in the GFS could infiltrate only at a certain rate, regardless of how much water was entering the GFS. The longer fertilized lengths contributed more water to the GFS than the shorter fertilized lengths, so the proportion of water and soluble N and P that infiltrated in the GFS was less for the longer fertilized lengths than for the shorter ones.

Our most recent work with the GFS has involved developing methods that allow one to determine how long a filter strip should be under a given set of conditions. In this study, we combined our experimental observations with other methods of predicting runoff and GFS performance to develop sets of charts and equations. These charts and equations can be used with field dimensions and readily-available crop, soil and rainfall data to easily determine what GFS length is required to reduce nutrient runoff to particular levels. A chart such as that given in **Figure 3**, can be used to select filter length for pasture on silt loam soil as a function of field length and GFS effectiveness.

Practical Considerations

Because of the way they operate, installation and maintenance of GFS are critical to ensure that they perform as expected. First, they should be installed on the contour, without regard to fence or property lines. The filters should be laid out upstream of any defined channels; i.e., the runoff should be filtered before it reaches the point that even small channels can be identified. Similarly, the filters should be maintained so that "sheet flow" occurs across the filter, as opposed to concentrated flow in even small channels. If channels develop within the GFS, then proportionately less runoff will infiltrate, decreasing the GFS' effectiveness. These considerations can make it difficult to designate and implement GFS areas, particularly in fields with irregular topography and having many low regions that function as small channels during runoff. Unless the GFS are properly installed, however, it could be questionable whether they provide any measurable benefit at all. Finally, the GFS should be fertilized. The amount of nutrient entering the GFS, as mentioned earlier, is quite small in agronomic terms. Additional fertilizer should be added as necessary to ensure a good stand of grass within the filter. Perhaps the best time to fertilize the GFS is some time after the first runoff has occurred from the fertilized field; this way, the GFS will be effective in filtering the most heavily concentrated runoff from the contributing field.

Summary

Our studies have shown that regardless of the source (organic or inorganic), runoff losses of N and P from fertilized pasture are relatively small proportions of the amount applied. These losses are also associated primarily with soluble N and P forms, rather than particulate forms, indicating that reducing erosion from pasture fields will have little impact on reducing nutrient losses. Grassed filter strips can be quite effective in reducing nutrient losses. The keys to using GFS to the best advantage are using the appropriate length and installing and maintaining them properly. We have developed methods to size GFS in general cases; but those wishing to use GFS should consult with USDA Natural Resources Conservation Service or Cooperative Extension Service personnel for the latest information specific to their locale. BC

Dr. Edwards is Associate Professor, Biosystems and Agricultural Engineering, University of Kentucky, Lexington; Dr. Moore is Soil Scientist, USDA-ARS, Fayetteville, AR. Dr. Daniel is Professor of Agronomy, University of Arkansas, Fayetteville.

PPI Announces T. Scott Murrell as Director for Northcentral Region

T. Scott Murrell has joined the staff of PPI as Northcentral Regional Director. He will be responsible for the agronomic research and education programs of the Institute.

"Scott Murrell has a great future with PPI and will contribute immensely to our organization," said Dr. David W. Dibb, President of PPI.

In 1986, Dr. Murrell earned a B.A. degree, with distinction, in general history at Purdue University. He did graduate work at Yale University before returning to Purdue, where he was awarded the M.S. degree in agronomy in 1991. He recently completed his Ph.D. degree in Soil Chemistry at Texas A&M University.

Over the past five years Dr. Murrell's study has centered around establishing interdisciplinary research between chemistry and soil science to investigate the mechanisms of phosphate reactions with iron oxides using techniques that analyze soil surfaces directly.

In his new responsibilities, he will direct PPI programs in North and South Dakota, Iowa, Minnesota, Nebraska and Wisconsin. His office is located in the Minneapolis-St. Paul area. BC

WESTERN CANADA

Potassium Fertigation of High Density Apple Orchards

By Denise Neilsen and Terry L. Roberts

Apple management in semi-arid, irrigated fruit growing regions of southern British Columbia, Canada, is undergoing rapid changes. Growers are replacing traditional low density orchards with high density systems containing 325 to more than 700 trees per acre. These high density orchards utilize new cultivars, dwarfing root stock and high frequency drip irrigation to supply water and plant nutrients.

Fertilizer application with drip irrigation is proving to be useful in improving nutrient management in high density orchards.

Fertilization with irrigation (fertigation) makes it easy to match nutrient application with plant growth. Small, frequent applications of fertilizer can be timed to the growth requirements of the trees. This is particularly important for high density plantings which must maximize early growth and yield. Fertigation provides greater flexibility in nutrient management, but it is not without some problems. High frequency drip irrigation concentrates root development in small volumes of soil beneath the irrigation emitter. Rapid acidification of this restricted soil volume has been observed due to the use of ammonium based fertilizers. The decline in pH affects nutrient availability and is causing growers to pay attention to nutrients for which they have not always been concerned, especially in the coarse textured soils typical of the region.

Acidification of the restricted soil volume near the soil surface and beneath

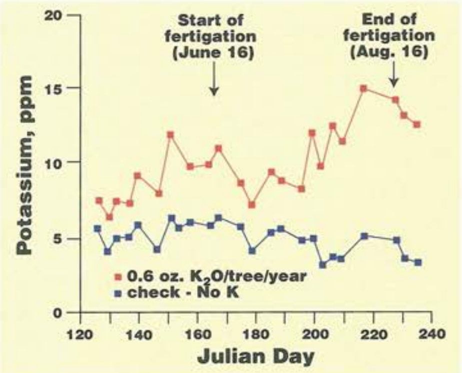

Figure 1. Soil solution K increases in response to K fertigation in a high density apple orchard in southern British Columbia.

HIGH DENSITY apple orchard with dwarf rootstock showing a drip irrigation system in southern British Columbia, Canada.

irrigation emitters is accompanied by leaching losses of plant nutrients. Two nutrients that appear to be most affected are potassium (K) and boron (B). A survey of 20 recently planted high density apple orchards in the Okanagan Valley of southern British Columbia showed that soil K beneath irrigation emitters was only 42 percent of K levels in the alley ways, and B was only 20 percent of that found in the alley ways. The reduced nutrient concentration in the root zone was reflected in lower leaf tissue concentrations and is causing nutritional problems in the apples. These orchards, most of which were only 2 to 5 years old, typically receive daily irrigation and multiple applications of nitrogen (N) and phosphorus (P) ... 0.35 to 1.4 oz. per tree ... in the first half of the growing season.

Such rapid changes in nutrient availability are causing researchers and growers to investigate methods of minimizing acidification and leaching losses and evaluate fertigation of additional nutrients.

Potassium is of particular interest because incidence of K deficiency in the Pacific Northwest region of North America has not previously been reported. Research conducted at Agriculture and Agri-Food Canada's Summerland Research Station is demonstrating that K deficiency in high density orchards can be alleviated. The graph in **Figure 1** shows how soil solution K levels below irrigation emitters can be increased and maintained through fertigation of 0.6 oz. K_2O per tree per year. In addition to increased availability of soil K, fertigation has also increased leaf K concentrations and fruit mineral content.

The positive influence of applied K on fruit yield is illustrated in **Table 1** with data from 3-year and 4-year-old apple trees. Potassium fertigation increased fruit yield by 12 percent in the younger trees and 20 percent in the older trees. Average fruit weight was increased 5 to 6 percent. Fruit quality was also improved and maturity hastened by K fertilization.

Results from these and other studies demonstrate the value in fertigating N, P and K in high density orchards. Nutritional problems developing with other nutrients will require further attention, but fertilizer application with drip irrigation is proving to be a valuable tool in nutrient management. BC

Dr. Neilsen is a Soil Scientist with Agriculture and Agri-Food Canada, Summerland, British Columbia. Dr. Roberts is Western Canada Director, PPI, Saskatoon, Saskatchewan.

TABLE 1. Potassium fertigation affects fruit yield of 3- and 4-year-old apple trees on dwarf rootstock.

	3-year-old trees		4-year-old trees	
K_2O Rate oz./tree/year	Yield, lb/tree	Mean fruit weight, oz.	Yield, lb/tree	Mean fruit weight, oz.
0	7.5	7.4	9.9	6.3
0.6	8.4	7.8	11.9	6.7

NEW JERSEY

Chloride Suppresses Corn Stalk Rot: Update

By J.R. Heckman and T.W. Bruulsema

Stalk rots are widespread diseases that reduce corn yield and quality. Lodging caused by stalk rot increases harvest losses and makes harvesting more difficult. Evidence that stalk rot may be reduced by fertilizers containing Cl was first obtained in New York state during the 1950s.

More recently, from 1990 to 1995, field experiments on Cl were conducted in New Jersey. The maximum yield environment used irrigation, narrow rows (12 in. wide) and high plant density (43,560 plants/A). Applications of nitrogen (N), phosphorus (P), and potassium (K) totaled 500 lb/A N, 268 P_2O_5 and 405 lb/A K_2O, applied at planting and during the growing season. Sulfur and micronutrients were also applied.

Chloride (Cl) supply is not generally considered to be a limiting factor for corn production in most field environments. However, more intensive production practices and higher yield levels may increase the need of corn for Cl. This article updates a preliminary report in *Better Crops with Plant Food*, Vol. 79, Issue 2, page 7.

The Cl treatment used KCl (muriate of potash) to supply 360 lb/A of Cl. The zero Cl treatment used potassium sulfate (K_2SO_4). Equal amounts of K were supplied to each. Stalk rot was evaluated at harvest on the first internode above the brace roots.

In the first three years of the experiments, yield responses of 8 to 26 bu/A were measured. The effects of Cl on stalk rots and lodging were noticeable in those years. In 1994 and 1995, significant reductions in stalk rot were measured (**Table 1**).

STALK ROT can be evaluated on corn near maturity using a thumb pressure test.

LODGING RESULTING from stalk rot can cause significant losses at harvest.

TABLE 1. Effect of Cl fertilization on grain yield and stalk rot, average of 1994 and 1995.

Treatment Cl, lb/A	Stalk rot, %	Grain yield, bu/A	Ear moisture, %	Stover moisture, %
0	18	243	29.1	64
360	7	259	29.5	67

The moisture content of the stover was greater in plants fertilized with Cl. Chloride may reduce stalk rot by preventing premature death of corn plants.

Applications should be based on soil and plant analysis. Soil tests for Cl are not commonly available but can be obtained by special request. Because Cl is easily lost from coarse-textured soils by leaching, spring application is advised where leaching is a problem. BC

Dr. Heckman is Specialist in Soil Fertility, Plant Science Department, Rutgers University, Brunswick, NJ 08903. Dr. Bruulsema is PPI Director, Eastern Canada and Northeast U.S., Guelph, Ontario, Canada.

Balanced Potassium Fertilization Fights Crop Disease

Plant disease problems are frequently magnified as a result of imbalanced plant nutrition. While plant nutrients are not the direct agent of disease control, they do augment the natural resistance mechanisms in crops.

Of all the plant nutrients, potassium (K) has been associated most often with helping to lower disease severity. That is not surprising considering the characteristics associated with K deficiencies. Those characteristics include thin cell walls, weak stalks and stems, smaller food transport vessels, fewer and less active stomata on the leaves, smaller and shorter roots, sugar accumulation in leaves, and accumulation of unusable nitrogen (N) compounds in stalks and leaves. Each of these lowers the ability of a crop to resist entry and infection by ever-present fungi, bacteria and virus disease organisms. A best management practice is to make sure that fertilization is adequate to avoid K deficiency-induced plant stresses.

Through the years, plant breeding programs have increased crop yield potential. Higher yield levels may increase N fertilizer requirements. It is important to balance higher N use with adequate K to avoid the stresses associated with unbalanced N:K levels. Imbalances occur most often during peak growing periods – the time most critical for building a sturdy plant capable of achieving its highest yield potential.

Healthy plants, free from stress, are much more resistant to disease attack. Use soil and tissue testing to make sure that K is not one of the limiting factors. Along with genetic resistance, a well-balanced fertilization program is the first line of defense against economic losses from crop diseases. BC

MIDWEST

Potassium in the Soil: Is It There or Isn't It? Some New Findings that May Explain Its Behavior

By Joseph W. Stucki

Because of its great importance as a plant nutrient, K in soils has been studied extensively. But in spite of these efforts, the fundamental chemical and physical phenomena that govern its fate, movement and plant availability have yet to be characterized fully. Soil tests for K often fail to reveal the true fertilizer demand in the field, resulting in unreliable and inefficient fertilizer recommendations.

Studies at the University of Illinois and Purdue University are shedding some light on factors that influence potassium (K) availability in soils. Soil conditions leading to chemical reduction of iron (Fe) have been shown to result in more K fixation in montmorillonitic clays.

Many factors contribute to this problem, but perhaps the one factor making the problem so intractable is that soil K is distributed among soluble, exchangeable, fixed, and insoluble forms, and can be redistributed among these forms in a rapid and unpredictable manner. Only that portion which is either soluble or exchangeable is available to the plant. This situation affects soil test recommendations for K because the form may change between the time of testing and the time the plant needs the nutrient, or it may change during the time between sampling in the field and analysis in the laboratory.

Early studies provided empirical evidence that K behavior is correlated with a number of different soil and environmental factors, such as the types of soil minerals present, moisture regime, cropping and fertilizer history, temperature fluctuations, and weathering. But no unified explanation linking all of these variables in a consistent manner has been established.

TABLE 1. Total, fixed and exchangeable K of oxidized and reduced clays.

Sample	Treatment	Fe^{++} % of total Fe	Total K	Fixed K meq/100 g	Exchangeable K
Montm. 1	Unreduced	0.16	93.0	2.9	90.1
	Reduced	74.00	122.3	31.5	90.8
Montm. 2	Unreduced	5.80	79.5	3.0	76.5
	Reduced	66.80	102.5	25.3	77.2
Illite	Unreduced	25.40	151.4	135.7	15.7
	Reduced	60.80	122.7	89.8	32.9
Drummer	Unreduced	9.50	102.4	72.8	29.6
(Dekalb)	Reduced	20.10	105.2	66.6	38.6
Drummer	Unreduced	6.94	105.3	71.6	33.7
(Urbana)	Reduced	66.80	105.3	65.7	39.6
Cisne	Unreduced	3.15	74.8	43.9	30.9
(Brownstone)	Reduced	61.50	82.1	39.2	42.9

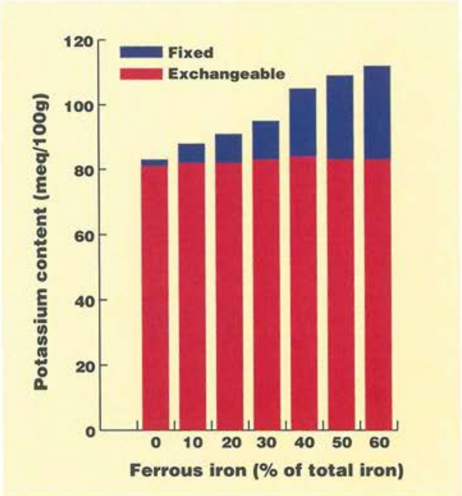

Figure 1. Fixed and exchangeable potassium.

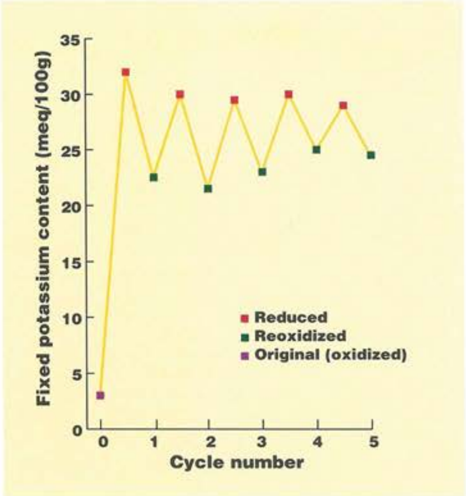

Figure 2. Redox cycle effects on fixation.

A Potential Breakthrough

A major step toward solving this problem was reached when researchers at Purdue University and the University of Illinois, in independent studies, reported a link between the oxidation state of Fe in the crystal structure of soil clay minerals and the amount of K fixation that occurred. Common oxidation states for Fe are ferric (Fe^{+++}) and ferrous (Fe^{++}).

These recent studies showed that the change in electrical charge at the mineral's surface that occurs during Fe reduction ($Fe^{+++} \rightarrow Fe^{++}$) increases the ability of the mineral to fix interlayer cations, including sodium (Na), calcium (Ca), copper (Cu), zinc (Zn) and K. The Purdue study showed a rapid increase in the non-exchangeable form of K with increased Fe^{++} content of freeze-dried soil clays and standard reference clays, in which the total K fixation capacity reached as high as 30 percent of the total cation exchange capacity.

The study at the University of Illinois followed the distribution of K between exchangeable and non-exchangeable fractions with increasing Fe^{++} content of undried montmorillonite. It found that K fixation increased steadily with increasing Fe^{++}. However, the exchangeable fraction remained almost constant (**Figure 1**).

The data in **Figure 1** can be used to estimate how much K in the soil would become fixed. For example, when 20 percent of the Fe is reduced ($Fe^{++} = 20$) the amount of fixation is about 10 meq/100 g of clay. In a soil having a clay content of 15 percent by weight, of which perhaps two-thirds would be montmorillonite, this translates into a fixed amount of K of about 900 lb K_2O/A. In other words, the oxidation state of Fe in the mineral is an extremely important factor for determining ion fixation in soil clay minerals. Outside of the studies cited above, this phenomenon has apparently been overlooked by soil fertility research, but appears to be a vital factor which must be taken into account.

Effects of Clay Mineral Type on K Fixation

The type of clay mineral present in the soil has a great impact on the fate of K. The calculations shown above are for a montmorillonite mineral. For other types of clay we found different behavior. Six

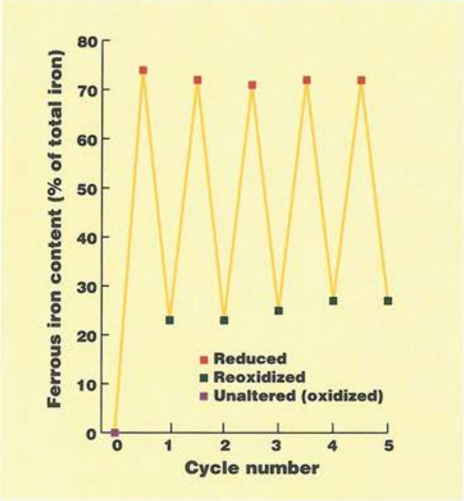

Figure 3. Redox cycle effects on ferrous iron.

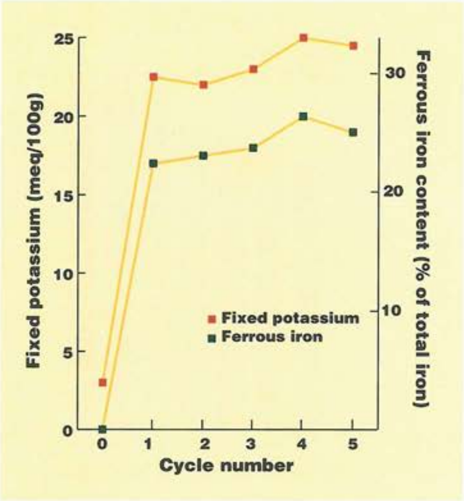

Figure 4. Reoxidized Montmorillonite.

different clays were studied, including two montmorillonites (expandable clay mineral), one illite (non-expandable clay mineral), and clay fractions from the A horizon of three Illinois soils (Drummer from Dekalb, Drummer from Urbana, and Cisne from Brownstown). Results indicated that illite behaved differently from montmorillonite and soil clays were more complicated, presumably due to the presence of mixtures of clay mineral types (**Table 1**).

The total and fixed K in montmorillonite increased when the clays (and Fe) were reduced, while the exchangeable K remained about constant. So structural Fe reduction increased K fixation in montmorillonite and would then be expected to decrease K availability in montmorillonite soils.

Illite behaved very differently from montmorillonite. The amount of fixed K decreased, rather than increased, upon Fe reduction and the amount of exchangeable K actually increased. The total K content of the illite also decreased when Fe was reduced, probably because illite initially contains a substantial amount of K, which is released during Fe reduction. Soils containing a mixture of illite and montmorillonite could then either fix or release K during reducing conditions (waterlogging, lowered oxygen content) depending on which clay dominates. If these minerals were present in the same amounts, no change in K availability would occur because the amount that one releases would be fixed by the other.

Studies of the soil clays revealed that the total K content of both Drummer soils remained about constant during Fe reduction, but varied slightly in the Cisne. The distribution of exchangeable and fixed K forms, however, fluctuated measurably, but less than in the montmorillonite and illite. The behavior of these soil clays appeared to be closer to that of illite than of montmorillonite. X-ray powder diffraction revealed that illite did comprise a significant portion of the clay fraction.

Effects of Redox Cycles on K Availability

Redox (reduction-oxidation) processes are common in nature, so the link between oxidation state and K fixation leads us to expect the distribution of K between available and non-available forms to change over space and time in the field. These processes repeat themselves because of wetting and drying cycles during the growing season, which cause the soil to alternate between oxidized and reduced states. Bacterial activity, which is affected by temperature and organic matter, also has a large effect on the oxidation state of the soil minerals and will rise and fall throughout the year. As these and other redox processes proceed throughout the season, and over the years, the distribution of K will be affected.

We attempted to mimic these processes by subjecting Fe-rich montmorillonite to six redox cycles in the laboratory. The amounts of Fe^{++} and fixed K were measured in the initial, reduced, and reoxidized state (which comprises one complete redox cycle) for each cycle. The results for K fixation during five redox cycles are shown in **Figure 2**. During each reduction step the amount of fixed K increased sharply, then decreased after reoxidation but failed to return to the pre-reduction level. With the completion of each cycle, the fixed K progressively increased, at first sharply then only gradually (**Figure 4**). The amount of Fe^{++} also increased sharply during the reduction step of each cycle, but reoxidation failed to restore all the Fe to the Fe^{+++} state (**Figure 3**). The amount of Fe^{++} remaining in the sample after reoxidation steadily increased with the completion of each cycle (**Figure 4**). This indicates that Fe^{++} in the clay is protected to some extent by the presence of K, presumably because of the collapse of superimposed clay layers. This same action could contribute to a stabilization of fixed K.

Summary

These results are encouraging, but much has yet to be learned because direct correlation between the control of oxidation state during soil tests and plant response to the resulting fertilizer recommendations have not been established. Some new ideas are emerging, however, and offer hope for the future. Perhaps we will soon be able to tell exactly how much K will be available to the plant during the growing season. BC

Dr. Stucki is with the Department of Natural Resources and Environmental Sciences, College of Agricultural, Consumer and Environmental Sciences, University of Illinois, Urbana, IL 61801.

Great Plains Soil Fertility Leadership Award to John T. Harapiak

Mr. John T. Harapiak is the 1996 recipient of the Great Plains Soil Fertility Leadership Award. The Award was presented during the Great Plains Soil Fertility Conference in Denver, CO. It recognizes individuals who have contributed substantially to the development of information and to education in the area of soil fertility, plant nutrition and fertilizer use.

Mr. Harapiak is Manager of Agronomic Services for Western Cooperative Fertilizers Limited (Westco). He is noted for development and promotion of the deep banding concept widely used in Prairie agriculture. Adoption of this technology has resulted in improved nitrogen use efficiency and economics for small grain producers. BC

Effects of Row Spacing, Seeding Rate and Seed-placed Phosphorus on Wheat and Barley in the Canadian Prairies

By G.P. Lafond, D. Domitruk, K.L. Bailey and D.A. Derksen

The general belief with spring cereals is that in order to maximize grain yields, narrow rows should be employed. However, we have found that when using a zero tillage production system, grain yields were similar for row spacings ranging from 4 to 12 inches. More recently, we have found that yields of barley and spring wheat were not affected under a conventional tillage fallow system with row spacings ranging also from 4 to 12 inches. The higher yields reported with narrow row spacings may be related to the amounts and placement of P fertilizer.

Studies in the thin black soil zone of Manitoba and Saskatchewan emphasize the importance of phosphorus (P) nutrition for enhancing crop establishment, reducing root diseases and increasing grain yields in wheat and barley.

Field studies were conducted to evaluate the effects of row spacing, seeding rate and seed-placed P on plant development, dry matter production, root diseases and grain yield in wheat and barley. We also wanted to determine if the response to P can be altered with changes in row spacing and/or seeding rate.

TABLE 1. Seed-placed P increases plant development of wheat and barley.

Seed-placed P_2O_5 rate, lb/A	Haun stage Barley	Haun stage Wheat
0	3.8	3.2
20	4.1	3.4
40	4.1	3.4

Averaged over 4 site-years.

Spring wheat and barley were grown at two locations near Brandon, Manitoba (Newdale clay loam) and Indian Head, Saskatchewan (Indian Head heavy clay) in 1993 and 1994. Three row spacings (4, 8 and 12 inches), three seeding rates (1, 2 and 3 bu/A) and three rates of P_2O_5 (0, 20 and 40 lb/A as monoammonium phosphate) were studied.

Plant Development

Row spacing had no effect on plant development in either wheat or barley, as measured by Haun stage. A Haun stage unit of 3.5 means there are three fully expanded leaves with the fourth being half the length of the third leaf. Increasing seeding rate tended to decrease plant development, but results were significant in only one of the four site-years. In all cases, seed-placed P increased Haun stage values (**Table 1**). In other words, the P caused quicker emergence, thus supporting the concept of the "pop-up" effect which is commonly observed in the northern Great Plains.

Root Diseases

The severity of root rot was expressed as the number of plants with greater than 50 percent of the sub-crown internode showing lesions and discoloration. Increasing the rate of seeding and adding

P fertilizer and increasing row spacing all decreased the severity of root rot in wheat and barley.

Above Ground Dry Matter Production and Grain Yield

In both wheat and barley, increasing the row spacing decreased total above ground dry matter at anthesis (**Table 2**). The largest decrease was from 4 to 8 inches, with little difference between 8 and 12 inches. As a rule, as row spacing increased, fewer plants and heads were established and produced, explaining in part the lower dry matter accumulation. Both seeding rate and seed-placed P increased dry matter production.

An interesting interaction between seeding rate and P fertilization was observed in about 25 percent of the trials, but the nature of the interaction varied with crop. In barley, response to applied P decreased as seed rate increased, with no response occurring at the highest seeding rate. However, unlike barley, the maximum yield in spring wheat occurred at the highest seeding and P application rates (**Table 3**). It appears that higher seeding rates will compensate for lower P application rates up to a point until available P supplies are exhausted, at which time additional P is required to maximize yields.

SPRING WHEAT in 12-inch row spacing.

Row spacing had no effect on grain production. The 12-inch spacing did not decrease grain yields of wheat and barley relative to the 4- and 8-inch spacings. Increasing seeding rate and seed-placed P improved grain yields of both wheat and barley. Barley responded to applied P in all site-years and wheat in three of the four site-years. Use of seed-placed P fertilizer at wide row spacings resulted in a higher concentration of P in the seed row. However, this did not improve the response to P (data not shown).

TABLE 2. Row spacing, seeding rate and seed-placed P affected total above ground dry matter production at anthesis and grain production.

	Dry matter, lb/A		Grain yield, bu/A	
	Barley	Wheat	Barley	Wheat
Row spacing, inches				
4	3,833	4,856	71	37
8	3,446	4,335	74	39
12	3,394	4,290	73	39
Seeding rate, bu/A				
1	3,362	4,240	68	36
2	3,610	4,728	74	39
3	3,681	4,877	77	40
Seed-placed P_2O_5, lb/A				
0	2,983	3,966	66	37
16	3,610	4,728	75	39
32	4,039	4,789	77	40

Averaged over 3 site-years

Summary

This study showed wider row spacings will not result in yield losses, increased root disease or delayed plant development. In fact, wide row spacings were shown to reduce the frequency of root diseases and "take-all" in wheat. Wider rows reduced dry matter production, but higher seeding rates increased dry matter production and tended to improve the response to applied P. Seed-placed P fertilizer hastened plant emergence and plant development, reduced root disease, and increased dry matter production and grain yields, thus reinforcing the importance of starter P. BC

Dr. Lafond, Dr. Bailey and Dr. Derksen are Research Scientists with Agriculture and Agri-Food Canada, located at Indian Head, SK, Saskatoon, SK and Brandon, MB, respectively. Dr. Domitruk is Land Management Specialist with Manitoba Agriculture, at Carman, MB.

TABLE 3. Seeding rate and seed-placed P interact to maximize spring wheat yields (Brandon, MB, 1994).

Seeding rate, bu/A	Applied P_2O_5, lb/A 0	20	40
	Grain yield, bu/A		
1	31	38	38
2	36	43	43

Robert E. Wagner Award Nominations Due

The Robert E. Wagner Award was established in 1988 by the PPI Board of Directors to recognize distinguished contributions to advanced crop yields through maximum yield research (MYR) and maximum economic yield (MEY) management. The MEY concept, also known as most efficient yield, can provide a solid foundation for better meeting world food needs.

The Award honors Dr. Wagner, retired President of PPI, for his many contributions to agriculture. He is widely recognized for originating the MEY management concept ... for more profitable, efficient agriculture.

Last year's recipients were Dr. L.D. Bailey of Agriculture and Agri-Food Canada's Brandon Research Centre (senior scientist category) and Mr. David Quipeng Zeng, Soil and Fertilizer Institute of the Guangdong Academy of Agricultural Sciences, People's Republic of China (young scientist category). The recipient in each category receives a $5,000 monetary award.

The format for preparation of nominations for this Award can be obtained by contacting the Potash & Phosphate Institute, 655 Engineering Drive, Suite 110, Norcross, Georgia 30092-2837; phone (770) 447-0335, ext. 203, fax (770) 448-0439. Private or public sector agronomists, crop scientists and soil scientists from all countries are eligible. Nominations must be received by December 31, 1996. BC

Production Notes

Managing Soil pH and Making the Most of Aglime

Liming and managing soil pH are important considerations for profitable crop production. Here are some guidelines to remember.

- Aglime performs best when applied early and incorporated into the soil. It takes time and moisture to gain the full benefit of aglime application for crops.
- If you need to increase the pH of a soil, either calcitic or dolomitic aglime will perform well. If soil test calls for adding magnesium (Mg), dolomitic limestone will supply Mg and increase pH. If soil neutralization is the only need, then the aglime that provides the best value is the wise choice.
- In no-till applications, the inability to mix aglime into the soil means that extra time is needed for the aglime to move down through the soil. You can only expect to change the soil pH about one-half inch of depth per year. The best practice is to lime to the maximum crop need and incorporate before the first no-till planting. If you are currently in no-till, apply aglime early and often. Follow these suggestions for pastures as well.
- Soil tests play a vital role in agriculture. Test early and follow recommendations to the best of your ability.
- Crop rotation is a best management practice. It is critical that soil tests are taken prior to crop rotation for optimum yields.
- The size of aglime particles determines how fast aglime will neutralize soil acidity and provide other benefits. Generally, the smaller the particle, the faster the pH change. Powder will dissolve within three months, sand size in a year, and BB size in three or more years.
- Pelletized lime is a very fine aglime that is held together by a water soluble binder. It is a great product for home and garden use or where the dust from bulk spreading is a problem.

Aglime offers many benefits:

- Neutralizes the soil, raises the pH
- Supplies vital calcium (Ca) and Mg (if dolomitic)
- Increases microbial activity
- Improves soil tilth
- Enhances the availability of other nutrients for plant growth.

Source: National Stone Association

CANADA

Cropping Effects on Phosphorus Leaching in Clay Soils

By R.R. Simard, C.F. Drury and J. Lafond

Subsurface runoff is now recognized as an important source of P contamination in surface waters of areas characterized by intensive animal production. This is particularly the case in the flat clay soils in cool and humid climates. These soils have a much smaller P storage capacity than comparable soils from warmer climates. The use of best management practices (BMPs) and conservation tillage, while effective in limiting surface erosion, does not always significantly reduce the amounts of P lost by drainage. The choice of crops may play an important role in the load of P from subsurface runoff.

> While losses of sediment by erosion have traditionally been considered the greatest source of the problem in eutrophication of aquatic systems, phosphorus (P) in subsurface water flow is now recognized as another important source. Recent findings indicate that total P losses to aquatic systems can actually be higher under legumes and forage crops than under corn or barley.

Subsurface water from tile drainage effluent under three cropping systems was analyzed over the 1961-1967 and 1980-1981 periods. This study was initiated in 1959 on a Brookston clay soil in southwestern Ontario. It included two fertilizer treatments (0 and 70 lb/A of P_2O_5) applied each year since 1960. The three cropping systems were continuous corn, a corn-oats-alfalfa-alfalfa rotation, and permanent Kentucky bluegrass. The results of the first period indicate limited effect of cropping systems, whereas P addition slightly increased P losses (**Table 1**). In European countries and in the U.S., a P concentration greater than 0.15 parts per million (ppm) is considered critical for the proliferation of algae.

The results of the fertilized plots from the second period indicate much larger losses to drainage water from the rotation plots than from continuous corn. The losses were particularly high under bluegrass. Even though no P fertilizer was added in the two alfalfa years, tile drainage P loss was still larger than under corn. In the unfertilized plots, P losses decreased between the first and second periods. However, crop yields were also reduced by 42 to 64 percent under these low soil fertility conditions.

What explains these observations? First of all, permanent forages (such as Kentucky bluegrass) are never plowed. Therefore, the network of biopores is never broken by the plow, and this may help the preferential flow of applied P to the drainage tiles. Further, the rotation crop is plowed under twice in the 4-year cycle (i.e. after corn and second year alfalfa). Secondly, grasses have greater root activity, and their roots exude more carbon (C) into the soil. Thirdly, organic acids from buried legume residues

TABLE 1. Average P content (ppm) of drainage water from soils cultivated to different crops in Harrow, Ontario.

Time period	Fertilizer	Monoculture corn	Rotation corn	Oats	1st year alfalfa	2nd year alfalfa	Kentucky bluegrass
1961-67	zero	0.17	0.20	0.17	0.20	0.18	0.17
	NPK	0.19	0.22	0.19	0.21	0.27	0.19
1980-81	zero	0.04	0.06	0.05	0.05	0.04	0.05
	NPK	0.14	0.39	0.47	0.48	0.39	1.10

diminish the P storage capacity. Phosphorus may migrate in organic forms along with dissolved organic C to reach the drainage system.

In addition to P in tile drainage water, surface runoff water was also monitored for dissolved and sediment P. In this experiment continuous corn had the highest sediment P in the surface runoff (data not shown). However, total dissolved P was much greater under sod than under continuous corn (**Table 2**). Rotation corn, oats and alfalfa had intermediate levels of surface water P losses.

TABLE 2. Total losses of phosphorus in surface runoff during growth of different crops in Harrow, Ontario.

Crop	Total P losses, lb/A
Continuous corn	0.69
Bluegrass sod	3.12
Rotation corn	1.09
Oats	1.25
First year alfalfa	1.10
Second year alfalfa	1.28

In a second study, we are investigating the effect of crops in a long-term experiment at our research farm at Normandin, Quebec. We have measured the amount of water soluble inorganic P in the subsoil of a clay at five times during the growing season: 15 days before and after seeding, 45 days after seeding, at harvest and 15 days after fall tillage operations. The results presented in **Figure 1** are averaged over six years (1989 to 1995). They clearly show that water soluble P content in the subsoil is much larger, particularly in the spring, under forages than under spring barley. This soil is rated as low in P by the Mehlich 3 soil test. Significant relationships were established between the amounts of water soluble C and P.

In the subsoil, a soluble P concentration greater than 1 part per million (ppm) is considered high. Although the mechanism is under investigation, results from these two studies indicate that subsoil runoff is potentially larger under forages than under cash crops in these cool and humid clay soils. This should be taken into consideration when implementing BMPs to reduce P losses to drainage waters in similar soils.

These findings radically alter the perception of the environmental impacts of cropping systems previously

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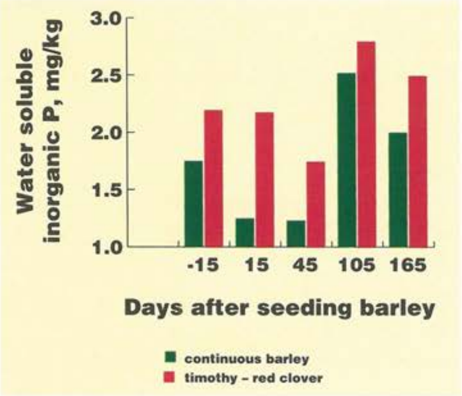

Figure 1. Water soluble P in the subsoil (2 to 3 ft. depth) of a Normandin clay soil in Quebec, averaged over the period 1989 to 1995.

ATLANTIC CANADA

Balanced Fertilizer Ensures Long-Term Timothy Productivity

By Gilles Bélanger and John E. Richards

Timothy is an important forage grass species in eastern Canada, the northeastern U.S., and many other temperate areas. Most studies of the fertilization of timothy have been concerned primarily with N or the interaction between N and K, and were conducted for only a few years.

The fertilizer requirements to ensure long-term productivity were studied over the last 35 years at the Fredericton Research Centre of Agriculture and Agri-Food Canada. All combinations of four rates of fertilizer N (0-240 lb N/A), P (0-90 lb P_2O_5/A), and K (0-150 lb K_2O/A) have been applied annually to timothy grown on an acid sandy loam soil. Two cuts of timothy were taken each year.

Timothy productivity was maintained for 26 years without reseeding when balanced applications of nitrogen (N), phosphorus (P), and potassium (K) were made. Persistence of timothy depended solely upon K fertilization. Long-term applications of N, P, and K also affected soil pH and the movement of P.

Yields

Forage yields approaching 3.8 tons/A were still obtained after 26 years of balanced N, P, and K fertilization. As a comparison, forage yields of newly seeded timothy fields range between 4.3 to 5.5 tons/A. Forage yields were increased by N, P, and K. The response to each applied nutrient was affected by the application of the other nutrients (**Figure 1**). Based on a fixed value for timothy hay and the market cost for the fertilizer, the most profitable rates of fertilization were approximately 140-90-120 lb/A of N, P_2O_5, and K_2O. In the first three years of this experiment (1960-1962), forage yield was limited primarily by N and K. The yield response to applied P, however, increased over 26 years. Timothy productivity was maintained after 26 years of continuous production without reseeding when balanced applications of the nutrients were made.

Botanical Composition

Long-term timothy persistence depended solely upon K fertilization (**Table 1**), a fact not evident in the first three years of the experiment. Over all plots, timothy comprised from 0 to 95 percent of the forage yield. In plots which received balanced applications of N, P, and K over 50 percent of the yield was due to timothy. Bentgrasses and bluegrasses were the major indigenous

TABLE 1. The effect of 26 years of K fertilization on the proportion of some grass species.

K_2O, lb/A	Timothy, %	Bluegrass, %	Bentgrass, %
0	16.2	36.5	22.1
50	41.7	14.9	9.2
100	49.1	11.4	6.9
150	57.8	9.3	5.2

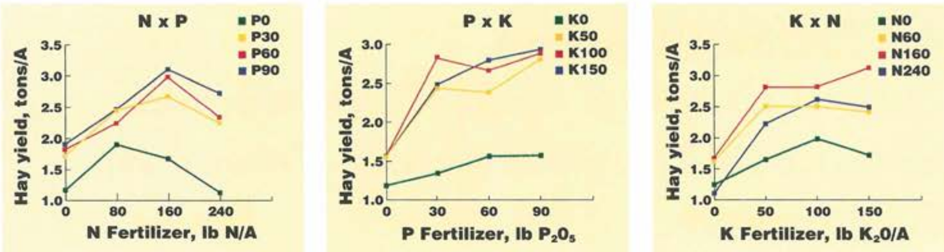

Figure 1. Effect of applied N, P, and K on total forage yield (average of 1985 and 1986). Forage yields expressed as hay at 18 percent moisture content.

species when low levels of K were applied. The proportion of bluegrass increased with increasing levels of applied P.

Soil

Applications of large amounts of N decreased soil pH of the topsoil by more than 1.3 units. This decrease was also observed at a depth of 18 inches. The decrease in pH, however, was less when P fertilizer was also applied because of the presence of calcium (Ca) in the superphosphate. Some fertilizer P was translocated into the 12- to 18-inch depth. The amount of P translocated increased with increasing rates of applied P.

Soil organic carbon (C) in the 0- to 6-inch layer ranged from 2.2 to 3.7 percent after 26 years and from 2.6 to 4.4 percent after 35 years. Organic C was greatest in plots with the lowest biomass production. Conversely, soil in plots with the greatest biomass production had the least amount of soil organic C. The differences were likely related to greater amounts of dry matter partitioned to non-harvested plant parts of the less productive forage species.

Conclusion

Long-term production of timothy is possible with balanced applications of N, P and K. The changes over time in response to P fertilizer, botanical composition, soil pH, and the movement of P would not have been predicted from short-term studies of three years or less. Fertility requirements of perennial forage crops are not well defined by field trials of short duration. BC

Dr. Bélanger and Dr. Richards are Research Scientists with the Research Branch of Agriculture and Agri-Food Canada, located at Ste-Foy, Quebec and St. John's, Newfoundland, respectively.

Cropping Effects... *(continued from page 25)*

considered desirable. While grass and forage crops protect soil from erosion and reduce impacts of sediment loss, corn and grain cultivation may have a more positive environmental impact when total P losses to aquatic systems are considered. BC

Dr. Simard, Dr. Drury and Mr. Lafond are research scientists with Agriculture and Agri-Food Canada in Ste-Foy, Quebec and Harrow, Ontario.

LOUISIANA

Annual Ryegrass Yield Response and Returns to Phosphorus and Potassium Fertilization

By D.L. Robinson and T.L. Eilers

Ryegrass is primarily utilized by grazing throughout the growing season. Historically, grazing has frequently been discontinued on a portion of the acreage during April and early May when forage production is most abundant and ryegrass is harvested as hay. Dairymen have recently begun preserving the ryegrass as silage or haylage rather than as hay. This practice is expanding rapidly because ryegrass silage is high in protein and digestibility and is an excellent complement to corn silage. Milk production from ryegrass silage has been excellent, reflecting the very high forage quality.

Mechanically harvesting ryegrass for hay or silage greatly increases the quantity of nutrients removed by the crop compared to that removed during grazing. Therefore, soil fertility practices become more important for ryegrass production as mechanical harvesting of the crop increases.

Although several studies have shown the effects of nitrogen (N) fertilizer practices on ryegrass production, very little information is available to show the effects of phosphorus (P) and potassium (K) on ryegrass production in Louisiana. A four-year study was completed in 1995 to help determine the P and K requirements for sustained ryegrass production on a low fertility Tangi silt loam soil at the Idlewild Research Station near Clinton. The study was conducted on plots previously used to evaluate effects of P and K rates on white clover production. The rates were not changed when the crop was changed from white clover to ryegrass.

Annual ryegrass is the most widely grown winter forage crop in Louisiana and throughout much of the southeastern U.S. If properly managed, it produces forage from early November until early May, although growth may stop or be very slow during the coldest period of January and February. It usually yields from 3 to 6 tons per acre and has the highest quality of any of the grasses grown in the region. Although it is normally planted every year, stand failures are rare and it commonly reseeds itself in many situations, making annual ryegrass a very dependable forage crop.

Phosphorus Effects on Ryegrass

The 4-year average results summarized in **Table 1** indicate that forage yield increased as P application increased to the highest level. However, a yield goal of near 90 percent of the maximum yield is generally recommended, and that yield level was obtained with 80 lb/A of P_2O_5. That P rate increased forage yield by 2 tons/A over the yield obtained with no added P, where only 48 percent of the maximum yield was obtained. The forage:P_2O_5 ratio indicates the pounds of forage produced for each pound of P_2O_5 applied. At 20 lb/A of P_2O_5, there was a yield increase of 119 lb of forage for each pound of applied P_2O_5, a very large return. The value decreased as the rate of applied P increased, as would be expected according to the law of diminishing returns. At 80 lb/A of P_2O_5, there was a return of 50 lb of forage per pound of P_2O_5, still a very favorable ratio.

Phosphorus concentration in the ryegrass and total P taken up by the crop increased as the rate of P application increased. Where no P was applied the ryegrass contained 0.13 percent P, and the crop removed 6 lb of P per acre from the soil. With 80 lb/A of applied P_2O_5, those values were 0.23 percent and 20 lb of P. The high P application rate of 320 lb/A of P_2O_5 increased P concentration in the ryegrass to 0.39 percent and P uptake to 38 lb/A, values well above the levels required for 90 percent of maximum yield.

Soil test P values were initially low and remained low at all P application rates of 80 lb/A of P_2O_5 or less, although values increased slightly even at low P application rates. At 160 and 320 lb/A of applied P_2O_5, soil tests reached medium and high levels, respectively. While the 80 lb/A rate of P_2O_5 produced nearly 90 percent of the maximum yield, it was insufficient to increase soil P levels appreciably while producing high yields of ryegrass during the four years of study.

Potassium Effects on Ryegrass

Potassium fertilizer effects on ryegrass are summarized in **Table 2** and indicate that forage yield increased as K application increased to the highest level. Again, as in the case of P application, 90 percent of the maximum yield was obtained well below the highest application rate, near 120 lb/A of K_2O. Furthermore, the yield increase due to applied K was much less than the increase due to applied P. Where no K was applied, the yield averaged 80 percent of the maximum yield. Application of 80 and 160 lb/A of K_2O increased the yield by only 0.4 and 0.6 ton/A, respectively, indicating about 0.5 ton/A yield increase at 120 lb/A of K_2O. The forage: K_2O ratios further reflect the low yield response to applied K. The highest ratio of 19 occurred at 20 lb/A and decreased to about 10 at 120 lb/A of K_2O, and to even smaller values at higher K rates.

Potassium concentration and total K uptake in the ryegrass increased with increasing K rates. Where no K was applied the crop contained 1.23 percent K and removed 102 lb of K per acre from the soil. Application of 80 lb/A of K_2O resulted in 1.56 percent K and 142 lb/A of K removal in the crop. Fertilizing with 120 lb/A of K_2O to produce 90 percent of the maximum yield would have caused the ryegrass to contain about 1.75 percent K and remove about 160 lb of K per acre.

TABLE 1. Phosphorus fertilizer influence on ryegrass yield, P removal, and soil test P levels of Tangi silt loam, 1992-1995.

P_2O_5 applied[1]	Yield of dry forage		Forage: P_2O_5 ratio	Forage P content		Soil test P, 1994
lb/A/yr.	tons/A	% of max.	lb/lb	%	lb/A	ppm
0	2.3	48	–	0.13	6	17
20	3.5	72	119	0.15	11	18
40	4.1	85	91	0.19	16	22
80	4.3	89	50	0.23	20	23
160	4.6	95	29	0.29	27	38
320	4.8	100	15	0.39	38	110

[1]Nitrogen was applied at planting and after each harvest at 50 lb/A.

The high K concentrations and total K removal in ryegrass at the 320 and 640 lb/A rates of K_2O show that the crop will absorb appreciably more K than it needs for maximum growth if the K is available in the soil. At the 640 lb/A K_2O rate, ryegrass contained over 3.5 percent K and removed over 360 lb of K per acre, more than twice the levels required to produce 90 percent of the maximum yield. These results are similar to the results obtained in the P study.

The two highest K rates depressed calcium (Ca) and magnesium (Mg) uptake by ryegrass. While Ca and Mg concentrations in the crop consistently declined with increasing K rates, the effect was most apparent at the two highest rates where K application exceeded the K requirement of ryegrass. The Ca and Mg concentrations at the highest K rate are low enough to cause deficiencies in ruminant animals, a fatal condition called grass tetany. Calculation of the grass tetany index, K/(Ca+Mg) equivalent ratio, at each K rate revealed that dangerously high indices consistently occurred at the highest rate of K_2O and occasionally at 320 lb/A of K_2O.

Soil test K values were initially low and remained low during this study at all rates of K application, although values were highest at the highest application rate. The low soil test values reflect the ability of ryegrass to absorb much larger quantities of K than it needs and further indicate that building up soil test K levels while harvesting high yields of ryegrass may not be practical or desirable. Basing K fertilization rates on the quantity of K removed in the crop would be more economical.

It appears that about 80 lb/A of P_2O_5 and 120 lb/A of K_2O are needed to sustain high yields of mechanically harvested ryegrass. Nutrient removal and fertilizer requirements would be much lower for ryegrass that is utilized by grazing.

Fertilization Costs and Returns

Costs and returns of ryegrass production are presented in **Table 3** from specific fertilizer combinations in which N was held constant at 200 lb/A while P and K rates were varied. Yields from **Table 1** and **2** were used to calculate returns per acre at forage values of \$60 and \$80 per ton. Returns above fertilizer costs were calculated to show the income available to pay all other production costs at the specific fertilizer rates.

It is apparent that total fertilizer costs did not increase greatly as P and K rates increased within the range where large yield responses occurred. Furthermore, increasing the forage value had a tremendous influence on returns above the fertilizer costs, emphasizing the importance of

TABLE 2. Potassium fertilizer influence on ryegrass yield, K removal, and soil test K levels of Tangi silt loam, 1992-1995.

K_2O_5 applied,[1] lb/A/yr	Yield of dry forage, ton/A	Yield of dry forage, % of max.	Forage: K_2O lb/lb	Forage mineral content: K %	K lb/A	Mg %	Ca %	Soil test K, ppm
0	4.1	60	–	1.23	102	0.31	0.67	49
20	4.3	64	19	1.25	110	0.31	0.69	35
40	4.4	86	15	1.33	116	0.30	0.66	30
80	4.5	88	11	1.56	142	0.28	0.64	31
160	4.7	93	8	1.97	188	0.27	0.61	34
320	4.9	96	5	2.84	258	0.23	0.56	23
640	5.1	100	3	3.50	362	0.18	0.46	76

[1]Nitrogen was applied at planting and after each harvest at 50 lb/A.

producing and marketing high quality forage through good management practices.

Returns above fertilizer costs increased as K_2O application rates increased to 60 and 120 lb/A, especially at the forage value of $80/ton. Returns to K application were less than returns to P application, reflecting the lower yield response to K than to P.

Summary

Annual ryegrass is utilized primarily by grazing beef and dairy animals but is also harvested as hay and silage. Mechanical harvesting of high-yielding ryegrass removes large quantities of P and K from the soil. A 4-year experiment with P and K fertilizer rates showed that high-yielding ryegrass required about 80 lb/A of P_2O_5 and 120 lb/A of K_2O to produce 90 percent of the maximum yield or about 4.5 tons/A when harvested mechanically. At that fertilization rate, the crop contained 0.23 percent P and 1.75 percent K, indicating that these levels were sufficient for the ryegrass but did not raise the low soil test P and K levels. Economic returns above fertilizer costs were maximized at or near the rates of 80 lb/A of P_2O_5 and 120 lb/A of K_2O in this study. BC

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TABLE 3. Costs and returns from fertilizing annual ryegrass for forage production in Louisiana.[1]

Fertilizers applied, lb/A $N-P_2O_5-K_2O$	Yield of dry forage, tons/A	$N-P_2O_5-K_2O$ Fertilizer $/A	Returns from forage $/A: Hay @ $80/ton, Total	Hay @ $80/ton, Above fert. cost	Hay @ $60/ton, Total	Hay @ $60/ton, Above fert. cost
200-0-120	2.3	78	185	107	139	61
200-40-120	4.4	86	330	242	247	159
200-80-120	4.3	98	344	246	258	180
200-160-120	4.6	118	370	252	277	169
200-320-120	4.8	158	387	229	290	132
200-80-0	4.1	80	329	249	247	167
200-80-60	4.4	89	358	269	268	179
200-80-120	4.6	98	371	273	278	180

[1]Fertilizer costs per acre were calculated by assuming N, P_2O_5 and K_2O costs to be 30, 25, and 15¢ per pound and the value of forage to be $80 and $60 per dry ton.

Cover Crops, Soil Quality, and Ecosystems Conference Set for March 12-14, 1997

The Soil and Water Conservation Society (SWCS) has scheduled a conference to look at the effects of cover crop management systems on soil quality in the context of soil pedons, watersheds and associated ecosystems. The program will be March 12-14, 1997 at Sacramento, California. PPI is a co-sponsor.

The conference will provide a forum for research scientists, farmers, agricultural advisers, product developers, and policy makers to discuss and identify possible enhancement of acceptability of such crop management systems. International community involvement is encouraged. More information is available from SWCS –

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Mediocrity—Our Goal?

To think is not enough...You must think of something.

Crime and health issues dominate our interests. Meanwhile a subtle change is occurring in our social structure. Are we headed toward mediocrity...resulting from our concept of equality...a society where everyone is entitled to everything everyone else has? Do talent, intelligence and diligence have less and less importance?

Not in the realm of agriculture! In farming, mediocrity is the sure road to failure. Suppose you produce 20 bushels of soybeans per acre while your neighbors produce 45 bushels. You won't have what they have, regardless of any concept of "100 percent coverage." Nor will it matter about your seniority, or your political connections, or your sex, or that you are a member of a minority group.

Farmers can't go on strike like professional baseball players or some labor groups. But they do have to be good—not mediocre—to succeed. They don't get anything just because they "deserve it" and their mistakes are not excused because they "had a tough time growing up."

As we try to avoid the path to mediocrity, farmers stand out as ones who **must** excel—if we are all to survive.

J. Fielding Reed

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