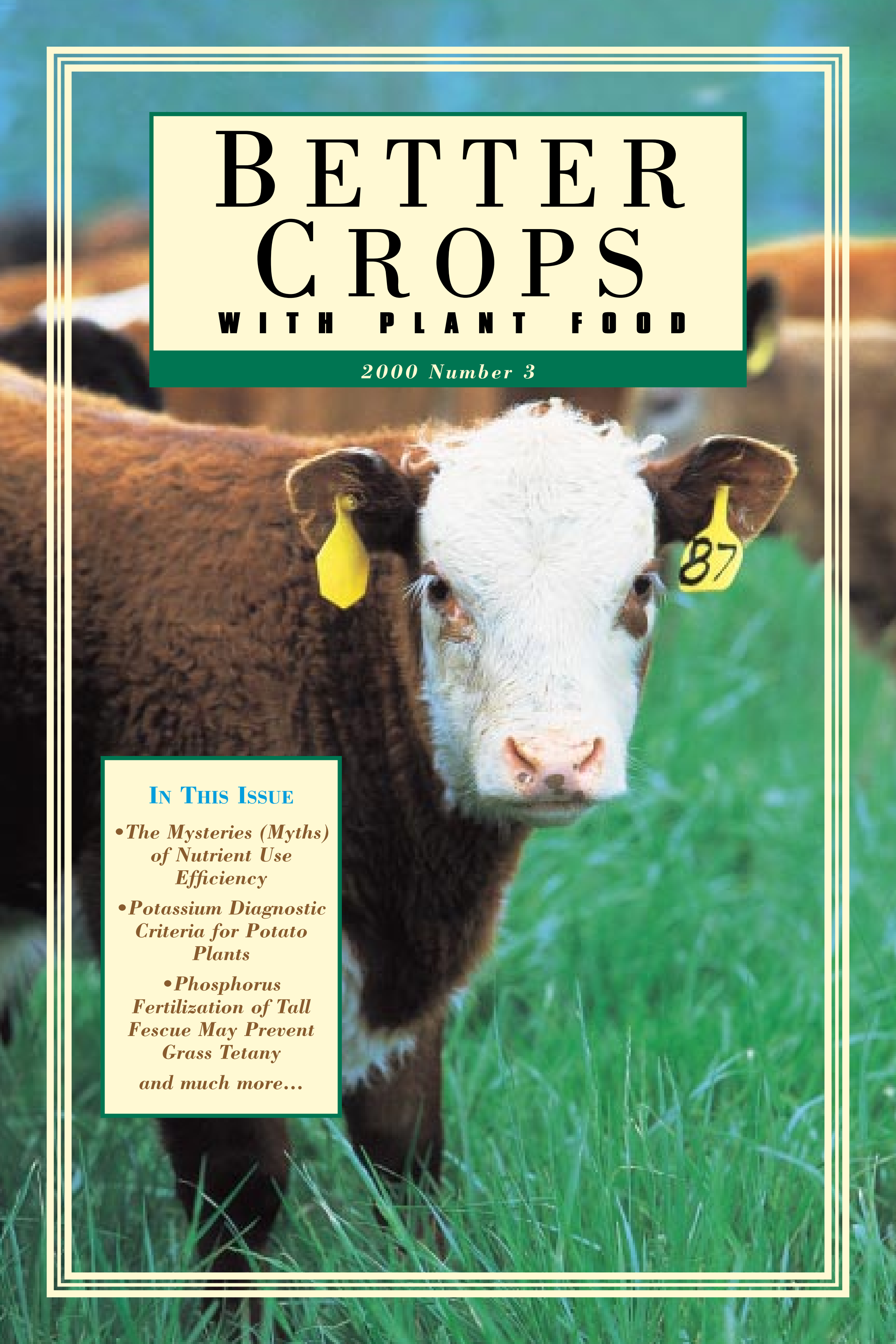
BETTER CROPS WITH PLANT FOOD

2000 Number 3



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- *Potassium Diagnostic Criteria for Potato Plants*
- *Phosphorus Fertilization of Tall Fescue May Prevent Grass Tetany*

and much more…

BETTER CROPS
WITH PLANT FOOD

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Our Cover: Crossbred calf on well-managed pasture.
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The Mysteries (Myths) of Nutrient Use Efficiency

By David W. Dibb

Nutrient use efficiency (NUE) is often misunderstood...or misrepresented...if it is discussed as an isolated issue and not in the context of the efficiency of the total crop production system. It is important to remember that efficiency and economic viability of the total food production system are objectives within which the various components need to be optimized to achieve overall goals.

> Inputs and resources do not function in isolation in biological systems, even though their individual efficiencies can be measured.

Where nutrients are purchased inputs, land is most often the primary limiting resource in terms of its availability. There are areas where more land could be brought into production, but most often those are marginal lands in terms of their production potential. Their exploitation would likely result in significantly increased costs in terms of pollution, loss of wildlife habitat, reduction of recreational areas, or elimination of other publicly perceived value. In other words, the most productive land is already being used. Thus, the most effective way of improving the system's efficiency is through continuous increases in yields. This will improve the efficiency of the system as a whole because the primary limiting resource (land) is more productive in terms of yield per unit farmed.

A classic crop response curve shows how NUE could be misrepresented or misinterpreted if the values and objectives of the system are ignored or forgotten. **Figure 1** illustrates the growth response of a crop to some needed input such as a deficient nutrient or nutrients. The Y-axis (vertical) represents a measure of potential yield, which would reach 100 percent if all necessary components were available in optimum quantities. The X-axis (horizontal) represents increasing application of needed nutrient inputs, assuming all other inputs and resources are nonlimiting. If any inputs are less than optimum, the curve may appear to be similar, but will peak at a lower yield and may not have as steep a slope. Or, if an input causes toxicity if over applied, the curve would turn down soon after the peak. There are several other variations that could make a family of curves, all of which would be below this highest yield potential curve.

In **Figure 1**, point C is the yield produced with only 'native' fertility supplied by the soil. None of the limiting nutrients have been applied. Point C represents the situation in many developing countries where yields are low because soils are infertile due to natural weathering processes or because they have

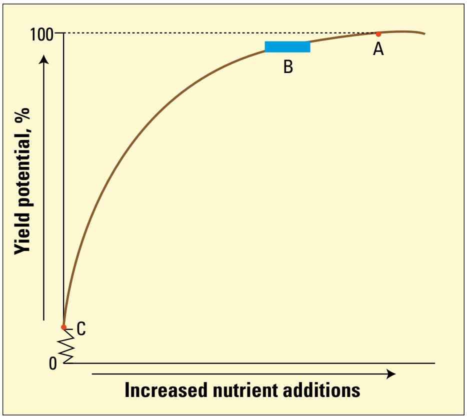

Figure 1. Classic crop response curve to added (limiting) nutrients.

been cropped for many years without replacing removed nutrients. Point A is the maximum yield potential at a given production site assuming all inputs are optimum. Point B is actually a range that depends on variables of cost and value which define the 'target' of the production system. This 'target' is where land use efficiency (LUE) is highest and where all other inputs and resources are interacting at their optimum level. It is just below the maximum yield potential. Within this range is also the economic optimum, where the greatest net return to inputs is achieved by the particular cropping system.

If we arbitrarily divide the response curve into four areas, we can discuss some general aspects of NUE and LUE and compare them for both developed and developing agriculture and see how some misconceptions may occur. We will label these areas I, II, III, and IV, from the bottom to the top of the response curve, illustrated in **Figure 2**.

Area I is at the bottom of the response curve. It is characterized by **very** low yields. Few nutrients are available or applied. Often the only nutrient application is through incorporation of limited crop residues or animal and human waste materials that may be available but not sufficient to move very far up the yield curve. Any addition of a limiting nutrient gives a relatively large response, as indicated by the steepness of the curve. Because yields are very low, LUE is very low. Environmental concerns are significant, since crops grow poorly and slowly, exposing the land for long periods to severe water and wind erosion losses. Paradoxically, NUE can be very high, because any small amount of nutrient applied could give a large yield response. Thus, if NUE is the only goal, it could be achieved here, but people will continue to starve because of the low total production. Many countries can be characterized as being on this part of the curve. Sub-Saharan Africa is a good example. Dr. Norman Borlaug has described the situation where a modest increase of 20 to 30 lb/A more nutrients along with improved varieties has increased yields by two, three, or four times. Yet, these higher yields are relatively low. They are still on the steepest part of the yield curve.

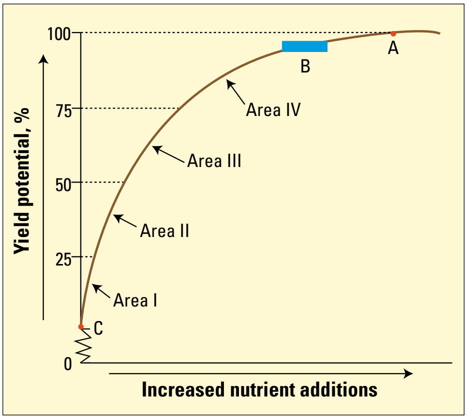

Figure 2. Nutrient use efficiency (NUE) and land use efficiency (LUE) are compatible.

Area II is a little higher on the yield curve, where agriculture begins to modernize, with new, higher yielding varieties that respond efficiently to nutrient inputs. Often there is an imbalance towards the use of nitrogen (N) to the exclusion or deficit of other nutrients...phosphorus (P) and potassium (K)...that could give additional response. While the yield curve has flattened a little, NUE may still be quite high for an individual added nutrient such as N, while other nutrients [P, K, sulfur (S), etc.] are being depleted from the soil. However, paradoxically, NUE can be lower than in Area I. Environmentally speaking, crop growth is not as vigorous as it could be; thus, wind and water erosion losses continue to be a big concern, and because N is used without proper balance with P and K, N loss potential can be large. LUE is not very good, because yields are well below the full potential that exists. India, which produces relatively low average yields versus the potential, might be in Area II. Nutrient use levels are only moderate, and there is considerable nutrient imbalance because of government policy decisions and economic availability. Many states from the former Soviet Union are falling back into this same area as they deplete their soils from lack of application of adequate nutrients, which has slipped to about 30 percent of former levels. Measured strictly by response to the meager levels of inputs now applied, the NUE may be quite high, but yields are declining, and future productivity is being robbed while LUE is dropping.

Area III is the part of the curve where there is still good response to added inputs. Yields are increasing, but the slope is less steep. In order to achieve these yields, improved balance in nutrient inputs must be observed, including additions of secondary [calcium (Ca), magnesium (Mg), and S] and micronutrients where deficient. Positive interactions among nutrients begin to take effect, and NUE improves. Plant growth is more vigorous, reducing potential wind and water erosion losses. More organic residue is produced, and with good management, erosion losses can be reduced even further. Because there is still some imbalance towards N, there is less than desirable efficiency of N use. China is a good example of a country that has moved in the last 10 to 15 years from Area II into Area III. They have worked hard to balance N-P-K ratios appropriately, including attention to secondary and micronutrients, and have seen yields increase accordingly. China has additional unrealized yield potential, is clearly moving up the yield curve, and will move further as nutrient input balance continues to improve. Nutrient use efficiency can be improved, but they have dramatically improved their LUE...and the economic return to the system from purchased inputs.

Interestingly, some production areas that were blessed with highly fertile soils started out in this Area III as their agriculture began to develop. Examples would be the Pampas of Argentina and the U.S. Midwest. In both places, crops were grown for many years without replacing nutrients that were being exported in harvested crops. Without attention to nutrient replacement, production will start to slip back from Area III to Area II. The U.S. started to pay attention to these deficits in the early 1950s as nutrient deficiencies began to be observed and corrected. Argentina is just beginning to go through this same transition, and nutrient applications are increasing.

Area IV is at the top of the yield curve. With attention to nutrient balance, NUE can be quite high while at the very top of the yield curve. LUE has reached its highest level. Crops grow vigorously and help protect the soil from wind and water erosion. Large amounts of crop residue are produced and, with proper management, can help to minimize or even eliminate erosion losses. If yields are moved into ‘range’ B, the economic optimum is also achieved, helping assure the sustainability of the system.

One might conclude that developed agricultures of North America and of Western Europe fall into this category...and they probably do. However, they still struggle with environmental concerns such as erosion losses and N and P in surface and ground waters, as well as economic viability. Why is this? In part, because most farmers are at the top of Area III or bottom of Area IV, and improvements can still be made. Whether through better nutrient balance and timing of application to improve NUE, or better management of crop residues to reduce erosion losses, or use of buffer strips to intercept potential nutrient losses, or myriad other decisions to increase yield and improve efficiency, farmers are trying to make improvements.

Few farmers achieve much higher than 75 or 80 percent of yield potential...even in the developed world. They are starting to use new tools, which have been referred to as part of ‘precision agriculture’ or, more accurately, ‘site-specific management’. All of these changes improve NUE to acceptable levels for a sustainable production agriculture that provides adequate food, fiber, feed, and fuel for all parts of the world. This is true NUE which resides in Area IV, not Areas I, II, or III, on the yield curve. NUE is optimized as a part of the total production system which maximizes LUE and economic return to all inputs...while protecting the environment. These components will define and determine sustainability now and for the future.

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IDAHO

Potassium Diagnostic Criteria for Potato Plants

By D.T. Westermann and T.A. Tindall

Potassium is required for the functionality of many plant enzyme systems, transport of starch and sugars, and osmotic regulation. It is highly mobile in both the xylem and phloem conductive tissues of plants. When plants are K deficient, they may be stunted, the younger leaves may develop a crinkly surface, and their margins roll downward. Leaves have slightly black pigmentation. Marginal scorching with necrotic spots may occur on older leaves (see photo).

Potassium (K) deficiency in Russet Burbank potatoes will not occur as long as petiole K concentrations remain above about 7 percent as determined by 'K balance' (total plant uptake/tuber uptake). Highest tuber yield and quality will be obtained when the K concentration of the petiole is kept above a 'K balance' concentration of 1.0 until about 20 days before scheduled vine kill or harvest.

Some plant disease symptoms can also mask K deficiency symptoms and will nearly always be present when potato plant K concentrations are marginal or low.

High yields are being achieved by many North American potato growers today. Production of 500 cwt/A can remove over 240 lb K_2O/A (200 lb K) in the tubers. Tubers become the dominant sink for carbohydrates and mobile inorganic nutrients during linear tuber bulking, often at the expense of the other vegetative portions of the plant. Most nutrient uptake occurs during this growth stage. As the plant matures, nutrients and dry matter in the tops and roots are also solubilized and translocated into the tubers. For highly mobile nutrients, such as K, the harvested tubers may contain over 90 percent of the total uptake, while only 10 to 20 percent of immobile nutrients are contained in the tubers.

Many potato growers apply a portion of the nutritional requirement as liquid fertilizers with the irrigation system. This practice provides an opportunity for a higher intensity of nutritional management during growth than possible with only preplant fertilization. This approach requires knowing the relationship between the nutrient concentration in a plant part and the nutrient status in the plant. For potatoes, this status can be defined as the ratio between the rate required by tuber growth divided by total plant uptake rate. When this ratio or balance is greater than 1.0, there is more nutrient uptake than required by tuber growth, so nutrients accumulate in the other vegetative portions of the plant or are available for additional growth. When the ratio is less than 1.0, uptake is less than that required for tuber growth, and mobile nutrients will be translocated out of the vegetative portions of the plant to the developing

Potassium deficiency symptoms during tuber growth of Russet Burbank potatoes.

tubers. This approach is currently being used for the nitrogen (N) and phosphorus (P) management of Russet Burbank potatoes using petiole nutrient concentrations.

When K availabilities and concentrations are relatively high, excessive K is translocated to the tubers, causing tuber dry matter to decrease because of increasing water content. Low K concentrations decrease tuber dry matter via a metabolic reduction in starch formation as well as reducing photosynthate needed for growth. The optimum tuber K concentration for highest dry matter is 1.8 percent on a dry matter basis. At this concentration, 0.4 lb K/A (0.48 lb K_2O/A) is required to grow 100 lb of fresh weight tubers. The goal of a K fertilization program for potatoes is to provide sufficient available K to achieve this concentration for all of tuber growth.

We undertook a study to develop a 'K balance' relationship for Russet Burbank potatoes from several field experiments established on grower fields in southern Idaho and northern Utah. There was a significant tuber yield and quality response to K fertilization in most experiments. Plant sampling started at early tuber growth (late June) and continued on about a 21 day interval until vines died or were killed prior to harvest. Plant samples consisted of petioles from the fourth leaf and the tops, tubers, and easily recoverable roots from a section of row.

Petiole K Response

Petiole K concentrations generally decrease with time after tuber initiation (**Figure 1**). The rate of decrease depends on plant/tuber growth rate and the amount of available K. The available K can come from soil, water, and recent fertilizer applications. Petiole concentrations can be very high initially when soil K availabilities are high or where large amounts of preplant K were applied. Fertilizer materials of greater solubility give higher petiole concentrations. Petiole K concentrations also respond to fertigation applications containing K.

We found that the petiole K concentration was linearly related to the K concentration in the photosynthetically active leaves. It was also significantly linearly related to the K concentrations in the above-ground plant parts and tubers. This indicates that K concentration in the fourth petiole is a good indication of the K status of the plant.

The relationship between the petiole K concentration and 'K balance' showed that the average K concentration was 6.4 percent when the 'K balance' was '1' (**Figure 2**). The 'K balance' and petiole concentration relationship was much better for individual experiments as it was dependent on the average tuber growth rate. The 'K balance' concentration varied between 5.4 and 7.3 percent K and was lower at the smaller tuber growth rates.

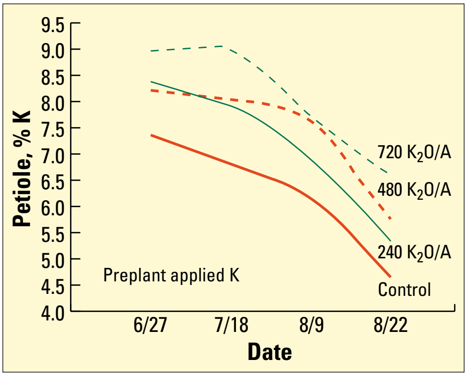

Figure 1. Typical changes in petiole K concentrations with time during Russet Burbank tuber growth.

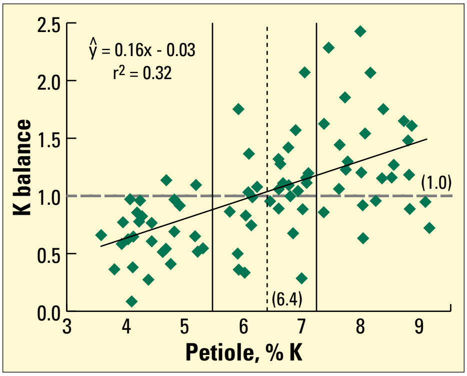

Figure 2. Relationship between petiole K concentrations and 'K balance' during Russet Burbank tuber growth. The lines on both sides of 6.4 show the range of K balances in seven individual experiments.

These data indicate that a K deficiency in Russet Burbank potatoes will not occur as long as petiole K concentrations remain above about 7 percent. Growers monitoring the K status of potato plants can use this concentration to schedule additional K materials via fertigation. Applications should be made 15 to 20 days before petioles reach this concentration for best results as there is a lag period for uptake to occur. Future petiole K concentrations may be estimated by plotting known concentrations against time and projecting the concentration trend line. This should be done for each field as the pattern of petiole K concentration with time is highly variable. For highest tuber yields and quality, K concentration of the petiole should be kept above the 'K balance' concentration until about 20 days before scheduled vine kill or harvest for best utilization of K sources. This will also allow tuber K concentration to decrease towards the optimum concentration.

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Research conducted with partial financial support from PPI, IMC Global (Great Salt Lake Minerals & Chemical Corporation), Agrium Inc. (Cominco Fertilizer Inc.), Idaho Potato Growers Association, and Idaho Fertilizer and Chemical Association.

Alberta:
Canadian Spring Canola Yields Keep Climbing

The report of a 71 bu/A spring canola yield featured in the recent article "High Yielding Canola Production" (*Better Crops with Plant Food* 84: 26-27) was out only for a short time when reports of even higher canola yields were received. Mr. Lenz Haderlein, a research agronomist with Agrium, reported a spring canola yield of 96 bu/A in 1996. These record yields were obtained from a potassium (K) response trial conducted at the University of Alberta Ellerslie Research Farm near Edmonton, Alberta. The trial site had been a long-term alfalfa-brome hay field, broken in fall 1994 and left fallow during 1995. The site had high background nitrogen (N) fertility (146 lb/A), marginal K (201 lb/A) and sulfur (S) levels (41 lb/A), and deficient phosphorus (P) levels (15 lb/A).

The spring canola cultivar Quantum (*Brassica napus*) was seeded on May 8 at 14 plants/sq. ft., with a side banded fertilizer application of 93 lb N/A, 31 lb P_2O_5/A, and 18 lb SO_4-S/A. The K was applied at rates of 0, 13, 27, or 40 lb K_2O/A as potassium chloride (KCl). Even though K levels were considered marginal by soil test at this site, there was no response to K additions. The 1996 growing season was characterized by abundant rainfall through June, July and August, with air temperatures cooler than the long-term normal and an open fall, free of any early frost. Across the six replicate, four treatment trial (24 plots total), canola yields ranged from a low of 82 bu/A to a high of 105 bu/A at a grain moisture content of 4.5 percent. These high yield results illustrate that when optimum environmental conditions are matched with superior cultivars and balanced nutrient management, high yields of spring canola are achievable in the sub-humid climate of western Canada.

Source: Mr. Lenz Haderlein, Research Agronomist, Agrium, Redwater, Alberta. E-mail: lhaderle@agrium.com and Dr. Adrian Johnston, Western Canada Director, PPI/PPIC, Saskatoon, Saskatchewan. E-mail: ajohnston@ppi-ppic.org

KANSAS

Effect of Phosphorus on Economic Nitrogen Rate for Irrigated Corn – Update

By K.C. Dhuyvetter, A.J. Schlegel, and T.L. Kastens

In an article in this publication about eight years ago, it was shown that P fertilizer increased yields considerably on irrigated corn in western Kansas (Schlegel and Dhuyvetter, *Better Crops with Plant Food*, Winter 1991-92). Furthermore, that article pointed out that the benefit of applying P had increased over time compared to where no P was applied due to initial soil P levels being depleted. It was also shown that P influenced the economically optimal N rate. These results were based on a long-term research project (1961-91) at the Kansas State University Southwest Research and Extension Center – Tribune Unit. In this research, fertilizer treatments included N rates ranging from 0 to 200 lb N/A in 40 lb increments, with and without P at a rate of 40 lb P_2O_5/A. Because of the significant response in yield in going from 0 to 40 lb P_2O_5/A, a logical question of the research was, "Was P a limiting factor on yield?" As a result of this question, starting in 1992 a higher rate of P (80 lb P_2O_5/A) treatment was added to the study. By adding this treatment, we can determine if P was a limiting factor. Additionally, by using the same analysis procedure, but for two different time periods, we can determine if the earlier results with regards to optimal fertilizer rates are robust.

Economic optimum rates of nitrogen (N) fertilization for irrigated corn are influenced by phosphorus (P). This article reports results of research in western Kansas.

Effect of Phosphorus Level on Yield

Figure 1 shows the yields by year for each of the P levels (0, 40, and 80 lb P_2O_5/A) averaged across all N rates. Applying P increased yields by over 50 bu/A, but there was almost no difference in yields between the 40 and 80 lb/A rates. While yield levels varied from year to year (e.g., 1995 had very low yields due to an early frost), the response to P was quite stable from year to year over this

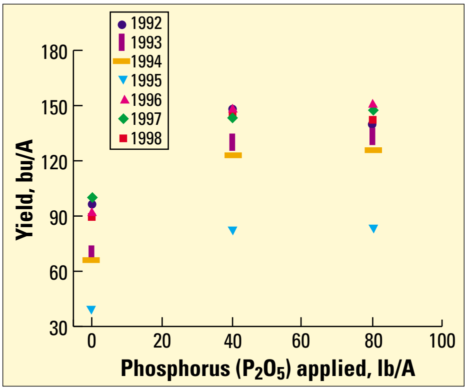

Figure 1. Irrigated corn yield for seven years versus applied P.

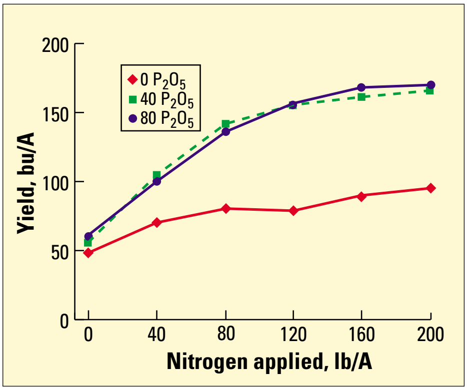

Figure 2. Irrigated corn yield versus N and P levels.

time period.

Figure 2 shows the relationship between yields and N rates for each of the P levels (averaged over years). Several observations can be made from this figure. First, applying P will undoubtedly be economical. Yields when P was applied are considerably greater than when none was applied. Secondly, optimal N rates most likely are different when P is applied compared to when it isn't (i.e., the curvature of the 40 and 80 lb/A lines are different from the 0 lb/A line). Lastly, while yields respond to P, there was no additional benefit to applying 80 lb/A compared to 40 lb/A, indicating that P is not a limiting factor in this study. Based on the graphical analysis of the data (**Figures 1** and **2**), it is readily apparent that of the three rates examined, the economically optimal level of P in this study is 40 lb/A.

TABLE 1. Results of estimating **Equation 1**.

	Parameter estimate	Standard error	*t*-value
Intercept (A_1)	73.006	2.371	30.80
(*Yr* - 1998) (A_2)	1.729	0.437	3.95
Yr95 (A_3)	-57.500	2.543	-23.00
N (B_1)	1.237	0.046	27.10
N2 (B_2)	-0.0034	0.0002	-15.72
R^2	0.864		
RMSE	17.818		

TABLE 2. Economic optimal N rate and model predicted 1998 yields.

	Scenario #1	Scenario #2	Scenario #3
Corn price, $/bu	1.75	2.25	2.75
Nitrogen price, $/lb	0.22	0.17	0.12
Optimal N rate, lb/A	161.4	168.6	173.3
1998 predicted yield at optimal N	183.0	183.7	184.0

Economic Optimal Level of Nitrogen

In order to estimate the optimal fertilizer N rate to apply, yield response functions are required. The yield response function used for this analysis is a quadratic. The quadratic function allows for yields to increase at a decreasing rate which is consistent with agronomic theory (i.e., decreasing marginal returns). However, a disadvantage of the quadratic is that at sufficiently high levels of fertilizer, predicted yields decrease rather than plateau. To alleviate this problem, it is often argued that a quadratic plateau is more appropriate than a simple quadratic. This analysis uses the simple quadratic function for several reasons. First, the earlier analysis (data from 1961 to 1991) was based on a quadratic; thus, for comparison purposes, the same functional form is used. Secondly, a visual appraisal of the yield-N relationship (**Figure 2**) suggests that a quadratic is probably a "reasonable fit" of the data in-sample. The yield response function estimated was the following:

Equation 1

$$Y = A_1 + A_2(Yr - 1998) + A_3 Yr95 + B_1 N + B_2 N^2$$

where Y is observed yield (bu/A), N is applied N (lb/A), (Yr - 1998) is a linear trend variable, $Yr95$ is a binary variable to account for the early frost in 1995, and the As and Bs are parameters to estimate. The results from estimating **Equation 1** are reported in **Table 1**. In-sample measures of goodness of fit (R^2 and *RMSE*) indicate that the quadratic functional form does reasonably well at explaining yield variability over years and N level. The linear trend variable indicates that yields increased 1.7 bushels per year, on average, over these seven years. On average, yields in 1995 were 57.5 bushels less than the other years.

Once the response function has been estimated, it is possible to determine the economically optimal N level given corn and

Optimal fertilization rates are needed for irrigated corn.

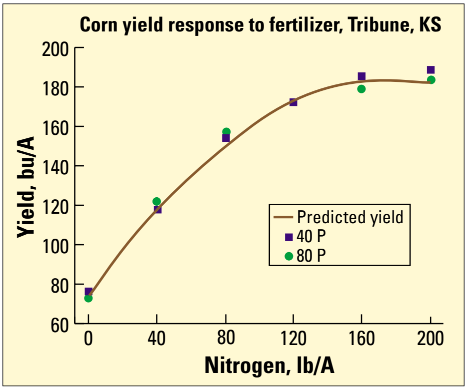

Figure 3. Model predicted yield response to N.

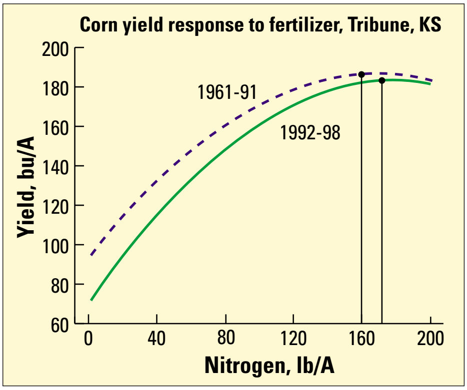

Figure 4. Model predicted yield response to N: 1961-91 vs. 1992-98.

N prices (remember that we have "declared" 40 lb of P_20_5 to be optimal based simply on a visual appraisal of the data). Determining optimal fertilizer levels is based on setting the derivative of the equation (dY/dN) equal to the input-output price ratio and solving for N. For example, $dY/dN = P_N/P_C$, where P_N is the price of N ($/lb) and P_C is the price of corn ($/bu), gives the economic optimal level of N to apply.

Table 2 shows the optimal fertilizer levels at three different corn-fertilizer price scenarios. The first price-cost scenario represents low corn prices and high fertilizer prices – a scenario that might result in "low" levels of fertilizer. Scenario 3 represents the opposite case (i.e., high corn prices and low fertilizer prices) where "high" fertilizer levels would be recommended. Scenario 2 represents average prices and costs. Optimal fertilizer rates are insensitive to corn and fertilizer prices, as the optimal N rate varied only 12 lb over the extreme price scenarios considered. The model-predicted yield is similar for all three scenarios because the quadratic functional form is relatively "flat" in the 160 to 180 lb range of N (**Figure 3**).

Figure 4 compares the trend-adjusted predicted yields for the 1961-91 and 1992-98 response functions. The curvature of the lines differs somewhat, indicating the yield-N relationship may have changed slightly. However, the economically optimal N rates are roughly comparable. Based on $2.50/bu corn and $0.15/lb N, the economically optimal N rate was 160 lb/A and 171 lb/A for the 1961-91 and 1992-98 response functions, respectively.

Summary

Optimal levels of N are dependent on P levels. Thus, when identifying optimal N rates, it is important that P is not a limiting factor. Based on 30 years of data, prior research indicated the optimal level of N on irrigated corn in western Kansas was approximately 160 lb/A. However, it was unclear whether P was a limiting factor in that study. Based on seven years of data with an additional rate of P, this analysis concludes that P was not a limiting factor in that earlier work and that economically optimal N rates have changed little over time.

Dr. Dhuyvetter and Dr. Kastens are associate and assistant professors, respectively, in the Agricultural Economics Department, and Dr. Schlegel is Professor at the Southwest Research-Extension Center, all with Kansas State University.

MISSOURI

Phosphorus Fertilization of Tall Fescue May Prevent Grass Tetany

By T.R. Lock, R.L. Kallenbach, D.G. Blevins, T.M. Reinbott, R.J. Crawford, Jr.,
M.D. Massie, and G.J. Bishop-Hurley

Preliminary results from Missouri research show that phosphorus (P) fertilization of tall fescue pastures growing on a soil low in P prevents blood serum magnesium (Mg) from decreasing in grazing cows.

Tall fescue (*Festuca arundinaceae* Shreb.) pastures cover nearly 35 million acres and provide feed for more than 80 percent of the beef cattle in the Midwest. The cool season grass is popular because it persists well on infertile, steeply sloped, and/or unmanaged soils common to pastures. In addition, it responds well to nitrogen (N) inputs and, if kept vegetative, is nutritious for livestock.

These attributes aside, producers can encounter problems with tall fescue. One common problem is that in early spring it is often low in Mg. Low Mg levels in the diet of lactating beef cows have been linked to a disease known as grass tetany. Cows suffering from grass tetany show symptoms such as nervousness and staggering in the early stages of the disease, but often become comatose and die within 24 hours after the initial symptoms are noticed. The disease costs cattle producers an estimated $300 million dollars annually in the U.S.

Grass tetany is a difficult disease to control. Many producers feed supplements containing elevated levels of Mg during the grass tetany season. In theory, this practice elevates the blood serum Mg status of the animal enough to prevent grass tetany. However, it is unreliable. A common ingredient in supplements is magnesium oxide (MgO). It is unpalatable to cattle, and intake among individual animals is variable. In addition, mineral supplements containing MgO are expensive and difficult to administer evenly to all animals grazing in a pasture.

Perhaps the most sensible way to prevent grass tetany would be to increase the Mg concentration of the grass in the pasture. Previous studies at the University of Missouri showed that soil P regulates Mg uptake in tall fescue. Greenhouse and small plot trials have consistently shown that plants growing on soils low in available P have a lower concentration of Mg in leaf tissue than plants that receive at least 57 lb P_2O_5/A. The greatest increase in leaf Mg usually occurs when P is applied to soils testing less than 16 lb Bray P-1/A. Interestingly, plants given Mg fertilizers often show no increase in leaf Mg unless P is applied with the Mg fertilizer.

Currently, no information exists to suggest that fertilizing tall fescue with P will increase the Mg enough to decrease the risk of grass tetany.


Tall fescue pastures are important for beef cattle production on millions of acres.

We conducted an experiment to determine if 1) applying P to tall fescue pasture can raise blood serum Mg in lactating beef cows, and 2) compare P fertilization to Mg mineral supplementation as a

TABLE 1. Blood serum Mg, Ca, K, and P concentrations at two dates in cows grazing tall fescue fertilized with P, cows receiving Mg mineral supplement while grazing, or cows grazing unfertilized tall fescue and receiving no Mg mineral supplement.

	2/15/00				3/28/00			
	Mg	Ca	K	P	Mg	Ca	K	P
Treatment	mg/dl[1]							
P fertilizer	1.84	6.05	25.3	5.59	1.72	7.35	26.9	6.24
Mg supplement	1.90	6.85	24.3	4.38	1.72	7.63	26.6	6.05
Control	1.89	6.06	25.6	4.99	1.47	7.52	26.4	4.90
$LSD_{0.10}$	NS	NS	NS	0.78	0.19	NS	NS	NS

[1] One mg/dl is equal to 10 parts per million (ppm).

means to protect against grass tetany.

Twenty-seven mature Angus cross cows in their third trimester of pregnancy grazed nine, two-acre tall fescue pastures from February 15 until April 11, 2000. Animals were assigned to one of three treatments. The treatments were:

1) Tall fescue fertilized with 100 lb P_2O_5/A
2) Magnesium mineral block supplied free choice, but with no P fertilizer
3) Control (no P fertilizer and no Mg mineral block).

The site was located in southwest Missouri, near Mt. Vernon. Soil tests at the end of the study showed 6 lb Bray P-1/A in unfertilized pastures and 29 lb P/A in pastures fertilized with P. All pastures were fertilized with 120 lb N/A and 300 lb K_2O/A in early spring. Blood samples were collected from each cow on February 15 and at 2-week intervals thereafter.

Blood Mineral Concentrations

All cattle had equal levels of blood serum Mg, potassium (K), and calcium (Ca) at the beginning of the study (February 15), and these levels were adequate for mature beef cows (**Table 1**). However, cows in the control treatment showed a 21 percent decrease in blood serum Mg level between February 15 and March 28. By contrast, there was no decrease in blood serum Mg when cows were supplemented with a Mg mineral block or were allowed to graze P fertilized pastures. This is significant because by March 28, most cows had reached peak lactation. Once cows reach peak lactation, their Mg requirement is approximately 22 grams per day, nearly double that before calving. Our preliminary data indicate that fertilizing tall fescue with P prevents blood Mg from falling during spring grazing and can protect against grass tetany. In fact, it may be more reliable than feeding Mg supplement free choice because differences in palatability and animal behavior could be eliminated as aggravating factors.

Although blood serum P was initially higher for the cows assigned to the P fertilized pastures, by the end of the study, blood serum K, Ca, and P were equal across the treatments. A preliminary analysis of the forage shows that P and Ca were higher when pastures were fertilized with P, but it appears that elevated levels of these minerals were not needed by the animals and likely were excreted.

Conclusion

In this study, adding 100 lb P_2O_5/A provided the same protection against grass tetany as supplying an expensive mineral supplement. This is important for producers because not only is grass tetany risk lowered, but adding P may also increase pasture productivity and livestock carrying capacity. BC

T.R. Lock is Graduate Research Assistant; R.L. Kallenbach is Extension Forage Crops Specialist and Assistant Professor; D.G. Blevins is Professor; T.M. Reinbott is Research Associate; and G.J. Bishop-Hurley is Post-Doctoral Fellow all in the Department of Agronomy, University of Missouri, Columbia, MO. R.J. Crawford, Jr. is Research Assistant Professor, and M.D. Massie is Senior Research Specialist at the Southwest Missouri Agricultural Research and Education Center, Mt. Vernon, MO.

Exchange Resins Measure Rotation Effect on Nutrient Availability

By Steven E. Salisbury and Neil W. Christensen

Differences in nitrogen (N), phosphorus (P), and potassium (K) availability resulting from crop rotation were measured using ion exchange resins. Resin probes quantitatively measured differences in availability of the yield-limiting nutrient and detected differences in nonlimiting nutrients.

One of the more promising methods for estimating nutrient availability involves ion exchange technology. This technology offers a way to eliminate problems inherent in chemical extraction of soil. Its use could lead to more refined fertilizer recommendations and benefit growers and the environment.

Ion exchangers are insoluble inorganic or organic synthetic materials that contain labile ions that can exchange with other ions in the surrounding medium. Similar natural processes include cation exchange by soil colloids and nutrient uptake by plants. Cation and anion exchangers are available in the form of resin beads, membranes or capsules.

One advantage of ion exchange resins over traditional soil extracts is the mechanistic relation between nutrient recovery by exchange resins and nutrient availability to plants. Ion diffusion is the primary mechanism controlling nutrient concentration at the plant root surface, especially for immobile nutrients such as P and K. Likewise, ion accumulation on exchange resins depends on ion concentration and rate of ion diffusion. Unlike chemical extracts of soil, ion accumulation by exchange resins depends on soil temperature and water content which affect both biological activity and ion diffusion. Because ion exchange resins buried in soil are exposed to the same conditions as plant roots, their nutrient recovery should reflect nutrient availability to plants.

Resin probes used to measure availability of cations and anions in soil solution.

Conventional soil testing measures the quantity of a nutrient available at the time of sampling, but may not account for factors affecting subsequent availability of a nutrient. Exchange resins can integrate the effects of biological, chemical, and physical processes influencing conversion of nutrients from organic to mineral form, transformation from one mineral form to another, and diffusion of ions to roots. They are useful in assessing differences in the nutrient supplying capacity of soil as affected by long-term

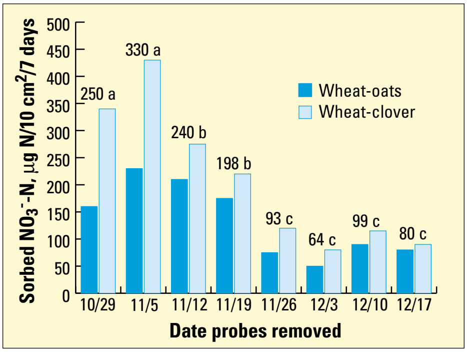

Figure 1. Nitrate N adsorbed by probes during seven-day intervals in fall 1998. The mean NO_3^--N adsorbed was significantly less ($P = 0.05$) for wheat following oats (132 µg/10 cm^2/7 days) than for wheat following clover (207 µg/10 cm^2/7 days).

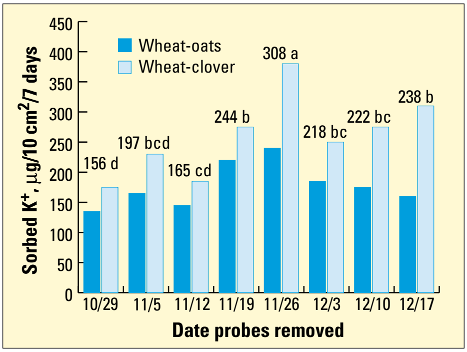

Figure 2. Potassium adsorbed by probes during seven-day intervals in fall 1998. The mean K^+ adsorbed was significantly less ($P = 0.05$) for wheat following oats (177 µg/10 cm^2/7 days) than for wheat following clover (260 µg/10 cm^2/7 days).

management such as crop rotation or fertilization history. Repeated measurements provide an assessment of the dynamics of nutrient supply over time.

Our study was designed to evaluate ion exchange resin technology for assessing nutrient availability to winter wheat grown in a crop rotation study where N was the only limiting nutrient. The Plant Root Simulator™ (PRS™) system, consisting of ion exchange resin membranes encapsulated in plastic probes (Western Ag Innovations, Saskatoon, SK, Canada), was used. The system includes two types of probes. Cation probes adsorb positively charged ions...ammonium (NH_4^+), K^+, calcium (Ca^{2+}), magnesium (Mg^{2+}), etc. Anion probes adsorb negatively charged ions... nitrate (NO_3^-), phosphate (PO_4^{3-}), sulfate (SO_4^{2-}), etc. Probes were installed in four replicate plots of unfertilized winter wheat that followed either spring oats or crimson clover. Measurements were made over an eight-week period beginning when wheat was planted on October 22. In each plot, three pairs of probes were installed at planting and removed one week later. This process was repeated each week over the next seven weeks. Probes removed from the soil were rinsed with distilled water and extracted with 0.5 M hydrochloric acid (HCl). Extracts were analyzed for NH_4^+-N, NO_3^--N, K^+, PO_4^{3-}, Ca^{2+}, and Mg^{2+}.

Plant and soil samples were also collected. One plant sample was taken at eight weeks after planting to estimate total biomass accumulation and nutrient uptake. Conventional soil samples were taken from the 0 to 4-inch depth at one, four, and eight weeks after planting. Plant and soil samples were analyzed for the same six nutrients as the probes.

On average, probes adsorbed significantly more NO_3^--N where winter wheat followed clover as compared to oats (**Figure 1**). However, NO_3^--N recovery by the probes depended on when measurements were made. Both NO_3^--N recovery and the difference between rotations were greater in the first few weeks after planting. Lowest levels of NO_3^--N were measured in weeks four through eight. Rainfall in excess of 7 inches during the last week of November probably leached NO_3^- below the probes. In addition to differences in NO_3^--N, significantly more NH_4^+-N was recovered where wheat followed clover (9.1 µg N/10 cm^2/7 days) as compared to oats (7.8 µg N/10 cm^2/7 days). Temporal effects on NH_4^+ were much less pronounced than for NO_3^-, but the lowest recovery of NH_4^+ was measured in week three when the soil was driest (data not shown).

While N was the only nutrient limiting wheat growth in the field, the previous crop

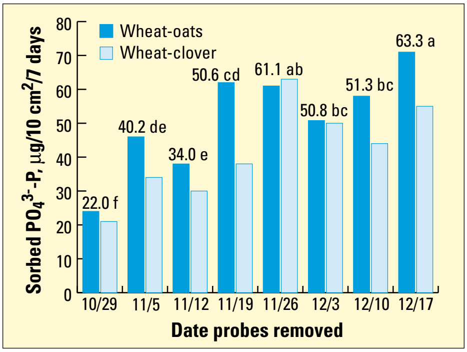

Figure 3. Phosphate-P adsorbed by probes during seven-day intervals in fall 1998. The mean PO_4^{3-}-P adsorbed was significantly less ($P = 0.05$) for wheat following clover (42 µg/10 cm^2/7 days) than for wheat following oats (51 µg/10 cm^2/7 days).

significantly influenced the amount of K^+ adsorbed by PRS™ probes (**Figure 2**). Probes recovered an average of 47 percent more K^+ where wheat followed clover than where wheat followed oats. Differences due to rotation were measured on all sampling dates, but were larger late in the sampling period (December 17) and when soil water content was very high (November 26). The crop rotation effect on K^+ availability was unexpected because K fertilizers had not been applied for at least four years, let alone applied differentially. Rotational differences in K^+ are most likely related to differences in the quantity, K content, and/or placement of residue from the previous crop.

In contrast to N and K, average PO_4^{3-}-P recovery by probes was significantly lower where wheat followed clover than where wheat followed oats (**Figure 3**). Probes recovered more PO_4^{3-}-P late in the sampling period when soil water content was at its highest. We are uncertain why PO_4^{3-}-P was more available after oats, but speculate that crimson clover may have been more efficient than oats in depleting soil P reserves.

Exchange resin recovery of N compared favorably with N uptake by winter wheat plants. Wheat plants grown after oats accumulated 63 percent as much N as wheat plants grown after clover by eight weeks of age. In comparison, probes in plots following oats adsorbed an average of 64 percent as much NO_3^--N as did probes in plots following clover. Even though K did not limit wheat growth, K concentration in wheat tissue and plant uptake of K were both greater where wheat followed clover. Phosphorus concentration in wheat tissue was unaffected by the previous crop, but P uptake was significantly greater following clover because of the growth response to increased N availability. Conventional soil tests detected crop rotation effects on NO_3^--N and K^+, but provided less sensitive measures of availability than did exchange resins.

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Robert E. Wagner Award Recipients Announced

Two outstanding agronomic scientists have been selected to receive the 1999-2000 Robert E. Wagner Award by the Potash & Phosphate Institute (PPI). The award encourages worldwide candidate nominations and has two categories...Senior Scientist and Young Scientist, under the age of 40. The recipient in each category receives $5,000 along with the award.

Dr. Kenneth G. Cassman, Professor and Head, Agronomy Department, University of Nebraska, was selected in the Senior Scientist Category. **Dr. Jeffrey J. Schoenau**, Research Scientist, University of Saskatchewan, receives the honor in the Young Scientist division.


Kenneth G. Cassman

The Robert E. Wagner Award recognizes distinguished contributions to advanced crop yields through maximum yield research (MYR) and maximum economic yield (MEY) management. The award honors Dr. Wagner, President (Retired) of PPI, for his many achievements and in recognition of his development of the MEY management concept...for profitable, efficient agriculture.

Dr. Cassman has made significant contributions to world cropping systems through his research, extension, and education achievements. Alleviating nutrient deficiencies of food and fiber crops to improve productivity, profit, and soil quality has been the focus of Dr. Cassman's work for the past 25 years. He has been widely recognized for significant contributions in major cropping systems for soybeans, cotton, rice, and corn.


Jeffrey J. Schoenau

Before accepting his current position at the University of Nebraska in 1996, Dr. Cassman was Systems Agronomist and Head, Division of Agronomy, Plant Physiology, and Agroecology, International Rice Research Institute, Philippines, from 1991 to 1995. From 1984 to 1990, he was Assistant and Associate Professor, Department of Agronomy and Range Science, University of California-Davis.

Since assuming his present role at Nebraska, Dr. Cassman has established an interdisciplinary team to investigate fundamental relationships among yield potential, nutrient and water efficiency, carbon sequestration, and profitability in corn and soybean production systems. He has received numerous awards and honors, including Fellow in American Society of Agronomy, Soil Science Society of America, and Crop Science Society of America.

Dr. Schoenau is Research Scientist in the Department of Soil Science and also an adjunct professor in the College of Graduate Studies and Research, University of Saskatchewan. He is the principal scientist of a strategic research program focused on soil management and fertility.

Since receiving his Ph.D. in 1988, Dr. Schoenau has become a leading expert in soil fertility management and plant nutrition, while carrying a significant undergraduate teaching load, supervising graduate students, and continuing other professional interests, including operation of the family farm.

Over the past decade, Dr. Schoenau has led a major research effort on soil fertility and plant nutrition in relation to conservation tillage practices on the Canadian prairies. This effort has formed the basis for traditional and new crops on a variety of soil types.

Dr. Schoenau received the Outstanding Young Agrologist Award of the Agricultural Institute of Canada in 1998 and has twice received recognition as Professor of the Year by the Agriculture Students' Association, University of Saskatchewan.

OKLAHOMA

Alfalfa Yield Response to Method and Rate of Applied Phosphorus

By R.W. Mullen, G.V. Johnson, J.F. Stritzke, J.L. Caddel, S.B. Phillips, and W.R. Raun

Alfalfa is an important forage legume crop in Oklahoma. It is preferred over other forage legumes due to its high yield potential, protein content, and palatability. The nitrogen (N) fixing capability of alfalfa decreases the need for N fertilizer, but places a higher demand on the soil for P and potassium (K). Phosphorus and K make up 0.2 to 0.5 percent and 1.0 to 2.0 percent of alfalfa forage, respectively. This implies that a field that produces 5 tons/A of alfalfa removes 20 to 50 lb P/A and 100 to 200 lb K/A annually from the soil which must be replenished from fertilization or soil mineral weathering. Typically, producers supply P annually to meet the needs of the crop and recharge depleted P pools. This research was conducted to evaluate the effect of high rates and banding of fertilizer P on alfalfa yield.

> Alfalfa response to a high rate of phosphorus (P) application was studied in a high yield environment.

An experiment was initiated in 1992 with treatments designed so that a total of 600 lb P_2O_5/A was applied over a six-year period. Fertilizer P was applied as diammonium phosphate (DAP, 18-46-0) broadcast (incorporated at planting) annually (100 lb P_2O_5/A/yr), biennially (200 lb P_2O_5/A/2-yr), and as a single fertilizer event (600 lb P_2O_5/A first year only); ammonium polyphosphate (APP, 10-34-0) knifed 6 inches below the surface on 20 inch spacing biennially (200 lb P_2O_5/A/2-yr) and as a single event (600 lb P_2O_5/A first year only). Two additional treatments were added to evaluate the effect of 500 lb K_2O/A/yr and 50 lb sulfur (S)/A/yr, each applied in conjunction with 200 lb P_2O_5/A/2-yr broadcast. The K treatment was included to identify when blanket applications should be made in order to eliminate or minimize available K as a yield limiting variable. Accordingly, the entire test site received blanket applications of 500 lb K_2O/A at establishment and in years three and five. Forage was

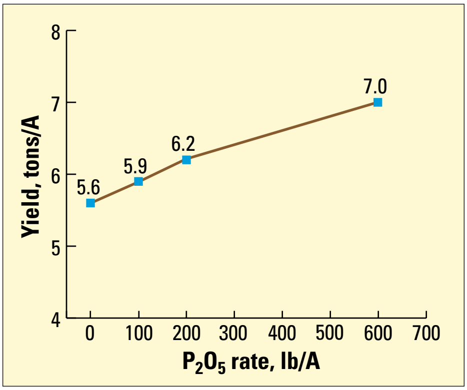

Figure 1. Alfalfa yield response in year one (1993) to DAP fertilization.

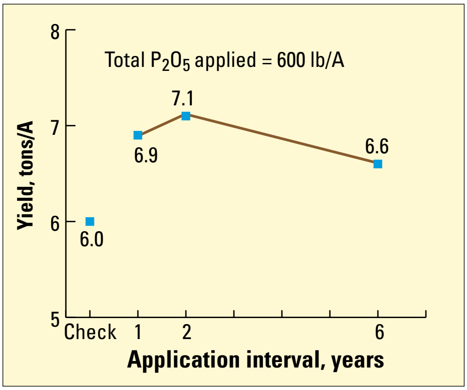

Figure 2. Alfalfa yield response in year six (1998) to DAP fertilization.

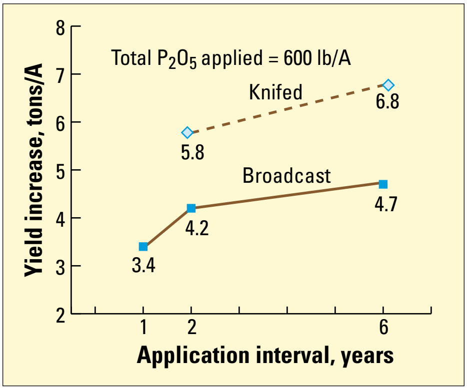

Figure 3. Total alfalfa yield increases from P fertilization (treatment minus check) after six years.

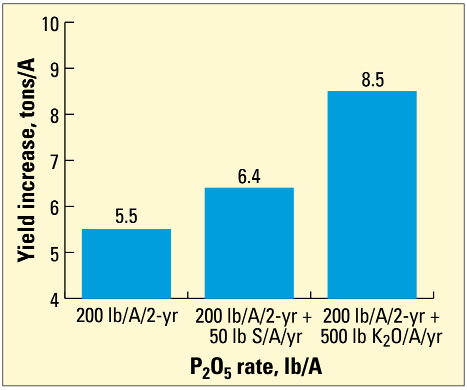

Figure 4. Total alfalfa yield increases (treatment minus check) from P, K, and S fertilization after six years.

usually harvested five times during the growing season (four times in 1997 and 1998) when 10 percent of the crop was flowering.

Alfalfa response to DAP fertilizer the first year showed a linear increase in yield with increasing P across the range of rates in the study (**Figure 1**). In 1998, the final year of the trial, yield response to the initial 600 lb P_2O_5/A treatment had decreased while plots that had received annual and biennial P fertilization still showed marked increases in yields above the check (**Figure 2**). Despite the drop in yield response late in the experiment to the 600 lb P_2O_5/A/6-yr, this treatment still yielded the highest of all DAP broadcast treatments over the six years of the experiment (**Figure 3**). Additionally, subsurface banding of APP stabilized alfalfa yields over the length of the trial, resulting in the highest yield over the six years of all P-only treatments (**Figure 3**).

These responses support the theory that banding of P increases availability by placing the nutrient in closer proximity to plant roots and minimizing soil-fertilizer reactions, maintaining availability for a longer period of time. Supplying a large amount (600 lb/A) of incorporated P at alfalfa establishment in a high yielding environment (e.g. irrigated) provides maximum response because plant density is high. As the stand ages and plant density decreases, availability of fertilizer P is lessened by reactions with soil, removal by crop uptake the first two years, and poorer extraction by a less dense root system. Smaller rates applied more frequently are better able to

(continued on page 23)

TABLE 1. Initial soil test of the entire experimental area.

NO_3-N	P	K	pH
	lb/A		
27.2	30.2	326	6.6

NO_3-N – 2M KCl extractant; P, K – Mehlich III; pH – 1:1 soil-water

TABLE 2. Soil test of selected treatments after six years.

Treatment	NO_3-N	P	K	pH
		lb/A		
Check	7.0	15.5	717	7.2
100 lb P_2O_5/A/yr	4.6	77.4	679	6.9
200 lb P_2O_5/A/2-yr	5.5	77.6	738	6.9
600 lb P_2O_5/A/6-yr	6.2	41	708	7.0
200 lb P_2O_5/A/2-yr (knifed)	5.8	78.3	693	6.8
600 lb P_2O_5/A/6-yr (knifed)	5.8	25.6	679	7.0
200 lb P_2O_5/A/2-yr + 500 lb K_2O/A/yr	5.6	59.8	1,135	6.5
200 lb P_2O_5/A/2-yr + 50 lb S/A/yr	5.3	69.3	648	7.1

NO_3-N – 2M KCl extractant; P, K – Mehlich III; pH – 1:1 soil-water

TEXAS

Rainfall and Runoff Water Quality from Croplands in the South Texas Coastal Plains

By Bobby R. Eddleman

Management practices used to produce crops (cotton, sorghum, corn) in the south Texas Coastal Plains are highly effective in limiting loads and yields of nutrients and pesticides in runoff.

The study area, called the Odem Ranch Watershed, encompassed 2,775 acres of cropland located near Edroy in western San Patricio County within the Nueces River Basin Drainage Area (**Figure 1**). Water-quality components were assessed for nutrients, pesticides, organic materials, and inorganic ions from rainfall and runoff. The scope of the study included types, concentrations, loads, and yields for nutrients in rainfall and runoff, along with selected pesticides in runoff. Rainfall samples were collected for 19 rainfall events of 0.25 inch or more during May 1, 1996 through December 31, 1997. Rainfall and runoff water samples also were collected for each storm event producing runoff from the watershed during 1996-1999. Total N and P were determined in rainfall samples. Total N and P, organic materials, selected pesticides, and inorganic ions were determined for runoff water samples. Event mean concentrations (EMCs), loads, and yields of nutrients and pesticides were quantified.

Rainfall and runoff water samples were collected from a 2,775-acre watershed used to produce crops. The samples were analyzed for water-quality constituents during 1995-1999. Loads and yields of nutrients...nitrogen (N) and phosphorus (P)...and pesticides (herbicides, insecticides, growth regulators, harvest aids) in runoff were minute in relation to nutrients and pesticides applied to crops. Croplands served as a sink for both N and P deposition in rainfall. Over five times more N in the form of ammonia (NH_3) and nitrate (NO_3) was deposited in rainfall than exited the watershed primarily as particulate organic N and NO_3 in runoff. Twice as much P was deposited in rainfall than exited the watershed as particulate P in runoff.

Hydrology

Rainfall and runoff from the watershed during the study period generally reflected the longer term rainfall pattern for the region, with runoff events interspersed between long periods when no runoff occurred. Cumulative rainfall and runoff for the watershed are shown in **Figure 2**. Rainfall totaled 109 inches during June 1995-May 1999. Seven rainfall events resulting in runoff at two sampling sites produced 5 inches (1,150 acre-ft) of runoff over four years. Runoff during storm events averaged 15 percent of rainfall and ranged from an average of less than 3 percent during the crop growing season (March-June) to an average of 22 percent during harvest and fall (August-October). However, runoff as a proportion of total rainfall on the watershed during June 1995 through May, 1999 was only 4.5 percent. Overall, four rain events with rainfall in excess of 4 inches and accounting for 23 percent of total rainfall on the watershed produced 84 percent of total runoff.

Rainfall Deposition

Deposition of rainfall constituents is the product of EMC for a constituent and rainfall volume. Deposition was measured in pounds per acre.

Nitrogen in rainfall occurs primarily as dissolved ammonia (NH_3) and dissolved nitrate (NO_3) which were detected in all rainfall samples (**Table 1**). Rainfall deposited an annual average of 3.0 lb of total N/A compared to 82 lb N/A/year applied to crops as N fertilizer, or about 3.5 percent of N input to croplands in the watershed.

Total P deposited on the watershed in rainfall amounted to 0.31 lb/A/year compared to 18.5 lb/A applied annually to crops as fertilizer.

TABLE 1. Annual N and P rainfall deposition, 1996-1998.

Constituents	1996	1997	1998	Average 1996-98
	lb/A			
Total nitrogen (as N)	2.10	3.86	3.12	3.03
Ammonia nitrogen (as N)	1.09	2.01	1.61	1.57
Nitrate-nitrogen (as N)	0.79	1.45	1.17	1.14
Total phosphorus (as P)	0.20	0.37	0.35	0.31
Orthophosphate (as P)	0.06	0.09	0.09	0.08

TABLE 2. Statistical summary of nutrient concentrations in runoff.

Constituents	Number of samples	Mean	Median	Maximum	Minimum
		ppm			
Total nitrogen (as N)	8	1.94	2.09	2.74	0.98
Ammonia nitrogen (as N)	10	0.08	0.05	0.24	<0.015
Nitrate-nitrogen (as N)	10	0.08	0.04	0.26	<0.01
Nitrate + nitrite-nitrogen (as N)	10	0.63	0.56	1.18	0.05
Ammonia + organic nitrogen, dissolved (as N)	8	0.38	0.41	0.64	<0.10
Ammonia + organic nitrogen, total (as N)	8	1.32	1.31	2.10	0.69
Total phosphorus (as P)	10	0.51	0.48	0.87	0.27
Dissolved phosphorus (as P)	8	0.26	0.24	0.45	<0.05
Orthophosphate, dissolved (as P)	10	0.24	0.25	0.41	<0.01

Concentrations of Nutrients and Pesticides in Runoff

Nutrient concentrations expressed as parts per million (ppm) were analyzed by computing summary statistics of the data to characterize cropland runoff-event concentrations (**Table 2**). None of the maximum values for nutrient concentrations listed in **Table 2** in runoff from the watershed exceeded any Texas Natural Resources Conservation Commission (TNRCC) standards or U.S. Environmental Protection Agency (EPA) drinking water quality standards.

Figure 1. Odem Ranch Watershed location.

Sixteen pesticides (10 herbicides and six insecticides) were detected with varying degrees of frequency in runoff samples. The

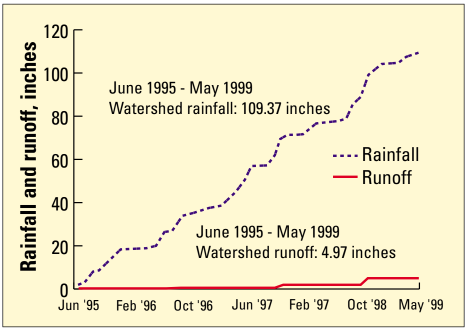

Figure 2. Odem Ranch Watershed monthly cumulative rainfall and runoff, June 1995-May 1999.

herbicide atrazine was detected in all samples. By-products deethyl atrazine and deisopropylatrazine were detected in 90 percent and 60 percent of samples, respectively.

Other herbicides detected in 50 percent or more of samples were metolachlor, trifluralin, fluometuron, and pendimethalin. Insecticides detected in 25 percent or less of all samples were malathion, azinphosmethyl, diazon, methyl parathion, and carbofuran.

TABLE 3. Annual nutrient and pesticide runoff yield, 1996-1998.

Constituents	1996	1997	1998	Average 1996-98
		lb/A		
Total nitrogen (as N)	0.162	0.667	0.800	0.54
Ammonia nitrogen (as N)	0.007	0.014	0.029	0.017
Nitrate + nitrite-nitrogen (as N)	0.061	0.272	0.104	0.146
Ammonia + organic nitrogen, total (as N)	0.088	0.396	0.725	0.403
Total phosphorus (as P)	0.038	0.147	0.261	0.149
Orthophosphate, dissolved (as P)	0.026	0.072	0.051	0.050
Atrazine + deethyl atrazine, dissolved	0.000228	0.000060	0.000055	0.000114
Fluometuron, dissolved	0.000086	0	0.000008	0.000031
Total other pesticides, dissolved[1]	0.000022	0.000035	0.000024	0.000027
Total pesticides	0.000336	0.000095	0.000087	0.000172

[1] Other pesticides consisted primarily of malathion, metolachlor, trifluralin, and pendimethalin in minute quantities.

Atrazine concentrations did not exceed EPA maximum contaminant levels (MCL) of 11 micrograms per liter, equivalent to 11 parts per billion (ppb), for human health and aquatic life protection. Maximum EMC values for all chemical constituents in runoff were less than EPA and TNRCC values for aquatic life and human health protection.

Constituent yield in runoff is the mass of a given constituent transported past a site during a specific time divided by drainage area of the watershed, measured in pounds per acre. Annual yields for nutrients and pesticides in runoff are provided in **Table 3**.

Total N yield ranged from 0.16 lb/A in 1996 to 0.8 lb/A in 1998, with a 1996-98 average of 0.54 lb/A/year. Total P yield averaged 0.15 lb/A/year during 1996-98.

Nitrogen applied as fertilizer far exceeds all other inputs to croplands in the watershed. Average annual fertilizer applications were 82 lb/A over the 1996-98 period compared to 3 lb/A from rainfall deposition and 0.54 lb/A in runoff.

Nitrogen in runoff represents 0.6 percent of N applied to crops as fertilizer and rainfall N. Forms of N entering the watershed differ from forms of N exiting it in runoff. Fertilizer N is applied as NH_3 and NO_3. Rainfall N consists primarily of NH_3 and NO_3. Runoff N is primarily (about 71 percent) organic N, and the organic N is primarily in particulate form (crop residue) rather than dissolved organic N.

Phosphorus applied as fertilizer to cropland averages 18.5 lb/A/year. Additional P, 0.31 lb/A/year, is deposited in rainfall. Phosphorus is applied as soluble orthophosphate. Total P yields in runoff from the watershed averaged 0.15 lb/A/year, with about a third as orthophosphate. Most P in runoff was in particulate form associated with crop residue and soil particles from soils that are naturally high in P content. Total P in runoff amounted to about 0.8 percent of combined P deposition in rainfall and applied orthophosphate to crops in the watershed.

Yield in runoff of all pesticides averaged 0.00017 lb/A/year. Total pesticide residues in runoff were quite small in all years, amounting to less than 1.0 lb for the entire 2,775-acre watershed. By comparison, 5.63 lb/A/year were applied to crops as insecticides (3.53 lb), herbicides (1.52 lb), and growth regulators and harvest aids (0.58 lb) over the 1996-98 period.

Data collected from seven storm events producing runoff during the June 1, 1996 through March 1999 period are representative of nutrient, pesticide, organic matter, and inorganic ions found in surface water runoff from croplands in the south Texas coastal plains. Loads and yields of nutrients and pesticides in runoff were minute in relation to nutrients and pesticides applied to cotton, sorghum, and corn crops. Nitrogen and P in runoff are comprised primarily of particulate organic N and particulate P from crop residues, whereas N and P applied to crops are NH_3 and NO_3-N and soluble orthophosphate.

Croplands serve as a sink for both N and P deposition in rainfall. Over five times more N in the form of NH_3 and NO_3 was deposited in rainfall than exited the watershed, primarily as particulate organic N and NO_3 in runoff. Twice as much P was deposited in rainfall than exited the watershed in runoff.

Changes in tillage practices, crop rotations, row spacings (e.g., ultra-narrow row plantings), plant populations, and amount of crop residue left in the soil have different implications for water quality in runoff since loads and yields of particulate organic N and particulate P may vary with cultural practices. However, results from this study and a companion study for southern Nueces and northern Kleberg counties indicate that with current production practices, crop agriculture poses little risk to the coastal environment in this area. BC

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Alfalfa Yield Response…

(continued from page 19)

sustain a P-rich environment that supports higher yields in the sixth year.

Potassium fertilizer also resulted in increased yields over the length of the experiment. The 200 lb P_2O_5/A/2-yr rate in conjunction with 500 lb K_2O/A/yr rate yielded the highest of all treatments over the six years (**Figure 4**). This response was somewhat surprising since the initial soil test of 326 lb/A was near the calibrated adequate level (K>350 lb/A), and the comparison treatment received 1,500 lb K_2O over the six-year period. Apparently, alfalfa responds to higher levels of available soil K in a high yielding environment. This statistically significant response of about 3 tons/A (value about $240) was from an input of an additional 1,500 lb K_2O (cost about $165) and would merit economic consideration. It is possible that lower annual rates (e.g. 250 to 300 lb K_2O/A) might have also supported this maximum yield and that the yield difference would have been even larger compared to a no-K treatment, not included in our study. Sulfur fertilization only slightly affected yield over the six years of the trial period.

Initial soil test levels are reported in **Table 1**. Final P soil test levels in the 600 lb P_2O_5/A initial treatment plots (both broadcast and injected) were significantly lower than treatments receiving annual and biennial P applications (**Table 2**). Soil test-P was significantly lower in the unfertilized check than for all other treatments. As expected, the treatment receiving 500 lb K_2O/A/yr had the highest K soil test value, while other plots which received only the initial and two subsequent 500 lb K_2O/A blanket treatments still had higher than what is commonly considered adequate levels of K in the soil (**Table 2**).

The response of alfalfa to high dose P fertilization has important economic implications. If a producer is able to maximize yields over a six-year period by supplying the fertilizer as a single event, additional profit may be realized because the implement and labor costs are decreased due to fewer fertilizer applications. It is important to note these yield responses of alfalfa to P and K fertilization may be unique to high yielding environments (e.g. irrigated areas). BC

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Are We There Yet?

More than 25 years separate me and Pat from the car trips we took with the kids. I'd be hard pressed to give much detail about any of those adventures, short or long. But there's one burning question that was common to all of them. "Are we there yet?" The interrogation usually began well before the "I have to go to the bathroom" phase took hold and grew more intense as we worked our way into the trip. Time has softened my remembrance of the aggravation that question caused. Truthfully, I would welcome the opportunity to answer it again...maybe more gently and patiently.

Now I find myself thinking about agriculture and wondering, "Are we there yet?" Sadly, I have to admit that we're not and won't be for some time to come.

Where is 'there' and why can't agriculture reach it? 'There' is agriculture's being recognized as the supplier of the most basic of man's necessities. Food. 'There' is agriculture's being appreciated as a group of men and women dedicated to feeding the world while protecting our natural resources of air, water and soil. 'There' is agriculture's being accepted as a part of the common community, doing its share...in the best way it knows how...to sustain the quality of life on this planet we all share.

The fertilizer industry, being a part of agriculture, isn't 'there' either. Far from it. A recent article in the *Globe and Mail*, Canada's national newspaper, made reference to the fact that U.S. farmers went easy on fertilizer use last year – "so they're all set to slather on the sinister gunk this year." I wonder if the writer knew that over a third of the food we produce in North America and perhaps 75 percent of that in some developing countries can be attributed to the use of that 'sinister gunk'. Dr. Tom Bruulsema, PPI's director for eastern Canada and the northeastern U.S., offered a credible rebuttal to the article when he wrote, "Is nourishing the soil to nourish the world a sinister activity? The farmers of North America deserve better credit."

Farmers do deserve better credit. So do agriculture and the fertilizer industry. If more of us would take the initiative, as did Dr. Bruulsema, perhaps that credit would eventually come. Then we could answer yes to the question, "Are we there yet?"

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