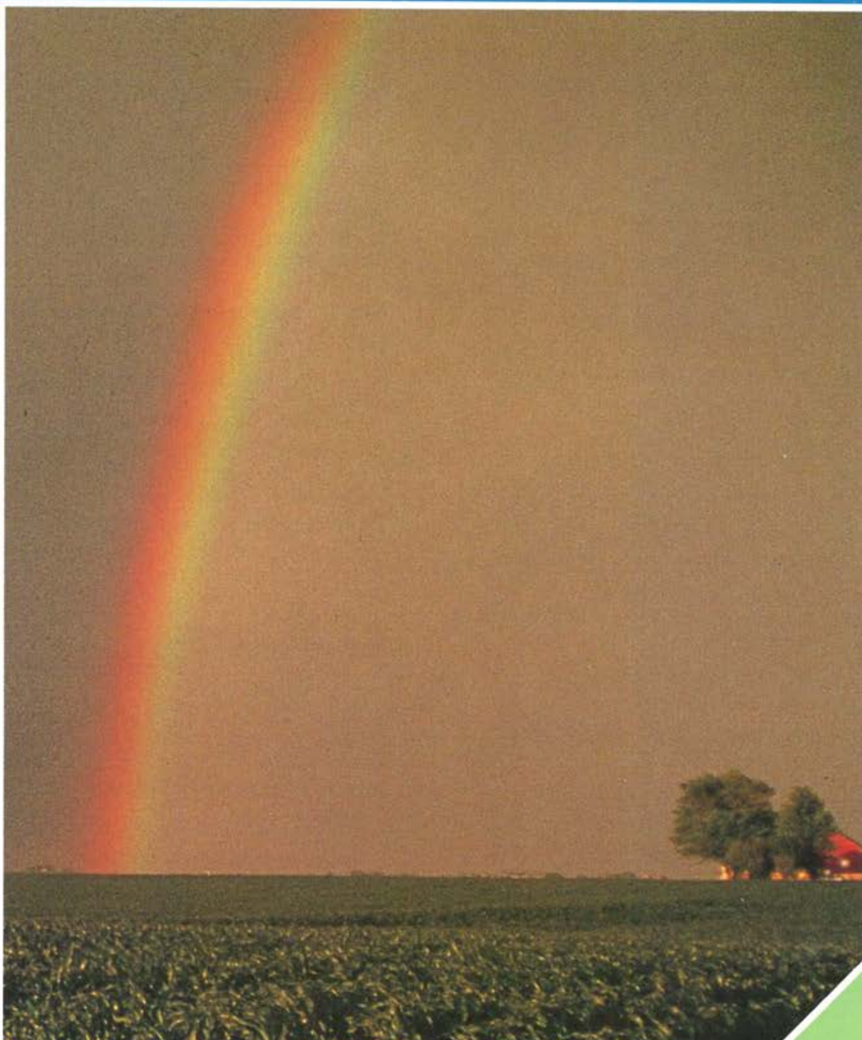
RESEARCH
EDUCATION

BETTER CROPS
WITH PLANT FOOD

Summer 1993



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BETTER CROPS With Plant Food

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Our Cover: A rainbow follows a thunderstorm over corn and soybean fields in Illinois.
Photo by Dr. Harold F. Reetz, Jr.

Extra Boron Maintains Root Growth under Toxic Aluminum Conditions

By Mary E. LeNoble, Dale G. Blevins and Randall J. Miles

Missouri research shows that boron (B) can help plants cope with toxic concentrations of exchangeable soil aluminum (Al).

ACIDIC, high Al soils are common throughout the United States and the world. In fact, Al toxicity limits yield to a greater degree than any other abiotic stress, except for drought. One of the first obvious effects of Al toxicity in plants is root growth inhibition. However, since high Al may exist in subsoil layers, impaired root growth generally goes unnoticed. Later, the above-ground plant may be stunted by a lack of nutrients and water, resulting in reduced yields.

Boron deficiency symptoms first appear as stunted root growth and many of the specific effects on root cell membranes and walls are identical to those reported for roots suffering from Al toxicity. Because these symptoms were so similar, we developed the hypothesis that Al toxicity may induce B deficiency in plants. The last few years we have completed a number of experiments to determine if higher than normal levels of B would alleviate symptoms of Al toxicity, specifically by increasing root growth.

Missouri Studies

We used a mini-rhizotron system in order to watch root growth of alfalfa in reconstructed soil. Our mini-rhizotron consisted of 3-inch diameter, 4-foot long PVC pipes with a portion of the wall removed and replaced with clear Plexiglas. The bottom half of the tube was filled with an acidic, high Al subsoil (Creldon silty clay loam, 9 to 15 inches below the surface, 26 percent exchangeable Al) from southwest Missouri. Then a layer of black potting soil was added to clearly define the soil zones. The top half of each tube was filled with a good central Missouri silt loam topsoil.

Alfalfa was planted in the tubes and tubes were placed in a rack in the greenhouse with the flat Plexiglas facing downward at an angle of 25 degrees off vertical so roots would grow along the clear surface. The tubes were covered with plywood and black plastic to keep the roots in darkness except when measurements or photographs were made. Analyses of both soils used in this experiment indicated that B levels were in the normal range. Some of the soils were supplemented with the equivalent of 2 lb/A B as boric acid before they were added to the rooting tubes. In one case only topsoil received B, in another case only the high Al soil received B, and in yet another case both topsoil and Al soil were treated with supplemental B. Control tubes received no B in either topsoil or Al soil. One set of tubes served as a double control in that it had the silt loam topsoil throughout the entire tube and did not receive supplemental B. **These tubes served to show that under our conditions, the high Al soil in the bottom half of the other tubes would actually inhibit root growth.**

Soil Studies

Dry weight of top growth measured at the end of the experiment was similar whether or not supplemental B was added to the soil. Top growth from the double control (topsoil throughout tube) had a greater dry weight than any of the treatments

(continued on next page)

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(Extra Boron . . . from page 3)

containing Al soil, confirming that the Al soil was toxic to top growth.

In order to monitor root growth, the tubes were uncovered weekly, and length of the longest root along the Plexiglas plate was measured. Roots grew identically through the topsoil with no effect of B treatment. However, after five weeks roots reached the high Al subsoil and treatment effects became apparent.

In tubes not supplemented with B, root growth was slowed considerably upon reaching the high Al soil compared to those in the all topsoil tube. So the high Al soil was toxic to root growth. **In tubes where both the topsoil and the high Al soil were supplemented with B, roots continued to grow into the Al soil (Figure 1).**

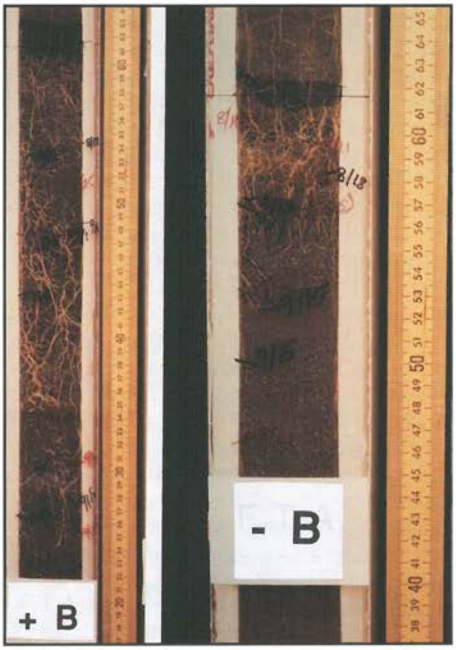

Figure 1. Root penetration into an Al soil layer with or without incorporated B is compared. The tube on the left contains topsoil and Al soil with B added to the topsoil and Al soil at a rate of 2 lb/A. At week 12, the roots had penetrated about 15 inches into the Al soil layer. The tube on the right contains topsoil and Al soil without B added. At week 12 the roots had penetrated only about 6 inches into the Al soil layer. (-B = without boron, +B = with boron)

Several different types of root measurements were made and all of them showed that B supplementation helped maintain root growth in the high Al soil. After 15 weeks, roots were removed from the tubes and total root lengths in the different soil zones determined. These measurements confirmed that supplemental B apparently helped maintain root growth in a normally toxic, high Al soil (**Figure 2**).

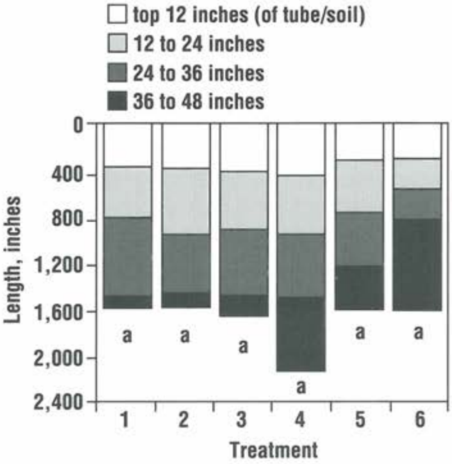

Figure 2. Alfalfa root length in four layers of soil as affected by B treatments. Soil-applied B helped maintain root growth in high Al soil under controlled conditions. (Treatments: 1 = Control; 2 = Foliar B; 3 = B in topsoil; 4 = B in topsoil and Al soil; 5 = Foliar B + B in topsoil and Al soil; 6 = No B, no Al soil.)

While an effect on top growth was not seen in our treatments with Al soil, whether or not B was added, the conditions of the experiments were such that nutrients and water were not limiting. In a field situation, limited root volume could produce nutrient and water stress and, as a result, decreased yield. Boron additions could cause deeper rooting depth in Al soil for better drought tolerance and exploration of larger soil volume, resulting in a greater potential for obtaining nutrients. Unfortunately, it is difficult to claim a direct B/Al interaction in a medium as complex as soil. Therefore, we decided to do some hydroponic or water experiments with a defined medium in order to prove a direct B/Al interaction.

Hydroponic Studies

Hydroponic experiments were conducted with both alfalfa and squash. Squash proved to be more vigorous and fast-growing under our hydroponic conditions. An Al concentration series was evaluated to find a concentration that would limit root growth. Then a B concentration series was used to find the optimum B concentration for root growth. Thereafter, a toxic Al concentration was used with a series of B concentrations ranging from deficient to beyond the normal levels.

When deficient or normal levels of B were used, Al caused severe root growth inhibition. At high levels of B, root growth was maintained even in the presence of Al (**Figure 3**).

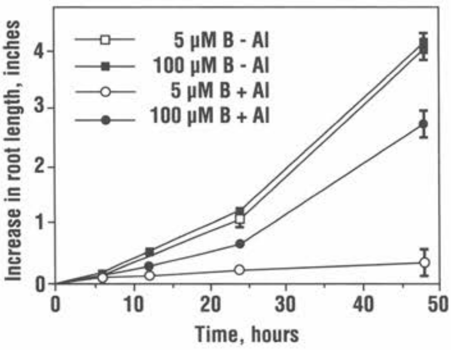

Figure 3. High concentrations of B in the growth medium in the presence of high concentations of Al significantly increased the growth of squash roots. Values are the means of 12 plants.

Conclusions

These experiments show that higher than normal B concentrations protected root growth in situations where high Al would normally be inhibitory. Like most research, these results raise a new question: Is the B requirement for normal plant growth and development higher under toxic Al conditions?

A word of caution–B is a micronutrient with a very narrow window for optimum plant growth and development. Care must be taken to increase the B levels, but not to the degree of toxicity. In addition, B does not replace lime in terms of raising soil pH or providing essential calcium (Ca). ■

1994 Meeting Dates Announced

GROWERS, agricultural supply industry personnel, researchers and Extension workers in the U.S. and Canada will want to take note of announced meeting dates for two conferences planned for March, 1994.

The **Great Plains Soil Fertility Conference is slated for March 8-9, 1994**, at the Stouffer Concourse Hotel, 3801 Quebec Street, Denver, Colorado. The program of this biennial event includes reports and discussion of current research and educational programs in soil fertility and crop production in the Great Plains states and Prairie provinces of the U.S. and Canada. Provinces and states included in the Conference are Alberta, Saskatchewan, Manitoba, Montana, North Dakota, Wyoming, South Dakota, Colorado, Nebraska, Kansas, Oklahoma, New Mexico and Texas.

A second meeting, the **1994 Intensive Wheat Management Conference, is planned for March 10-11** in Denver, also at the Stouffer Concourse Hotel. This Conference, the fifth in a series covering the U.S. and Canada, will focus on improved wheat management for more efficient production, higher yields, and higher profitability. The program will highlight technology transfer and implementation of best management practices. Research reports will also be included.

Registration materials and program specifics will be available for both meetings in the Fall of 1993. For more information contact the Potash & Phosphate Institute, 2805 Claflin Road, Suite 200, Manhattan, KS 66502, phone 913-776-0273.

Fertilizer: To Nourish Infertile Soil that Feeds a Fertile Population that Crowds a Fragile World

By Norman E. Borlaug and Christopher R. Dowswell

This article is a summary of the keynote address, presented by the authors, at the 61st Annual Conference, International Fertilizer Industry Association (IFA), May 1993, in New Orleans, LA.

THE ONLY WAY for agriculture to produce sufficient food to keep pace with population and to alleviate the hunger of the world's poor is to increase the intensity of agricultural production in those ecological conditions which lend themselves to intensification while decreasing the intensity of production in the more fragile ecologies.

Most of the increases in food production needed over the next several generations must be achieved through yield increases on land now under cultivation. Moreover, these yield increases must be achieved through the application of technology already available or well advanced in the research pipeline. This will not only lead to economic development but it will also do much to solve the serious environmental problems that come as a consequence of trying to cultivate lands that are not suited to crop production. Fortunately, many of the more-favored agricultural lands currently under cultivation are still producing food at yield levels far below their potential.

"Moreover, these yield increases must be achieved through the application of technology already available . . . it will also do much to solve the serious environmental problems that come as a consequence of trying to cultivate lands that are not suited to crop production."


Dr. N.E. Borlaug

Given present scientific know-how, the use of chemical fertilizers must be expanded two to three-fold in developing countries over the next 20 years if the world is to feed herself. Of course, the greatest need is in sub-Saharan Africa, which faces the horrifying prospect of producing only 75 percent of its food requirements by the year 2000, unless fertilizer use is tripled and combined with higher-yielding varieties and improved crop management practices. Surely, raising the average use of plant nutrients from less than 10 kg/ha (9 lb/A) to something like 30 kg/ha (27 lb/A) cannot be an environmental problem, only an environmental solution. Fertilizer use also must be expanded in Latin America–especially in the favored lands of Argentina, Brazil and Uruguay–and in South Asia, where the Green Revolution appears to have lost its momentum.

To achieve the needed production increases and to distribute the food equitably in the low-income, food-deficit countries will require the sustained and

Dr. Norman E. Borlaug is Senior Consultant, International Maize and Wheat Improvement Center (CIMMYT), and President of the Sasakawa Africa Association (SAA). He was awarded the Nobel prize for his work in plant breeding and improvement; he is considered a leader of the "Green Revolution" which brought tremendous increases in wheat and rice yields in Asia beginning in the 1960s.
Dr. Christopher R. Dowswell is Director for Program Coordination of SAA.

focused support of governments, international development agencies, and the private agribusiness sector. This task will not and cannot be achieved without major new investments in the agricultural sectors of the developing countries, particularly in the areas of transportation, fertilizer and seed supply, and water resource development.

At the closure of the Rio Summit, 425 members of the scientific and intellectual community presented to the Heads of State and Government what is now being called the Heidelberg Appeal. Since then, nearly 3,000 scientists at last count have signed. Permit us to quote the last paragraph of the Appeal:

"The greatest evils which stalk our Earth are ignorance and oppression, and not Science, Technology and Industry, whose instruments, when adequately managed, are indispensable tools of a future shaped by Humanity, by itself and for itself, in overcoming major problems like overpopulation, starvation and world-wide diseases."

"Given present scientific know-how, the use of chemical fertilizers must be expanded two to three-fold in developing countries over the next 20 years if the world is to feed herself."

For those of us on the food production front, let us all remember that world peace will not–and cannot–be built on empty stomachs. Deny farmers access to modern factors of production–such as improved varieties, fertilizers and crop protection chemicals–and the world will be doomed –not from poisoning, as some say, but from starvation and social chaos. ■

OPPORTUNITIES for increased crop production exist in most regions of the world. Improved agronomic practices are essential for progress in developing countries.

The Importance of Potassium in Strenuous Exercise Programs

By D.B. Young

The minutes immediately after cessation of strenuous exercise are termed the "vulnerable period" or the period of "post-exercise peril" regarding the occurrence of lethal cardiac arrhythmias. During the first minutes after strenuous exercise, the blood serum concentrations of catecholamines increase, while whole serum potassium (K) concentrations rapidly decline, possibly contributing to "post-exercise peril."

THE TERM "post-exercise peril" or "vulnerable period" is used to describe the period of the first few minutes immediately following strenuous exercise, when the risk of cardiac arrhythmias is greatest. During this time, blood plasma concentrations of catecholamines (a group of sympathomimetic amines including epinephrine, also called adrenaline, and norepinephrine) rise to seven to nine times their normal levels while blood serum K falls precipitously. Epinephrine is a powerful vasopressor that can accelerate the heart rate.

Our research used healthy men volunteers in a standard exercise regimen that required approximately 15 minutes of treadmill work at increasing levels of intensity until exhaustion was reached. Blood samples were taken at a resting stage prior to the exercise period and at 1, 2, 3, 5 and 10 minutes following the exercise. The samples were analyzed for K, sodium (Na), pH, epinephrine and norepinephrine.

At the initiation of post-exercise sampling, the test subjects had levels of catecholamines that were seven to nine times above resting values (**Figure 1**). Their plasma K concentrations are shown in **Figure 2**. Plasma K concentration rose slightly during exercise to about 1 meq/L above the pre-exercise level. The concentration then fell rapidly over the next 5 minutes to near the resting concentration.

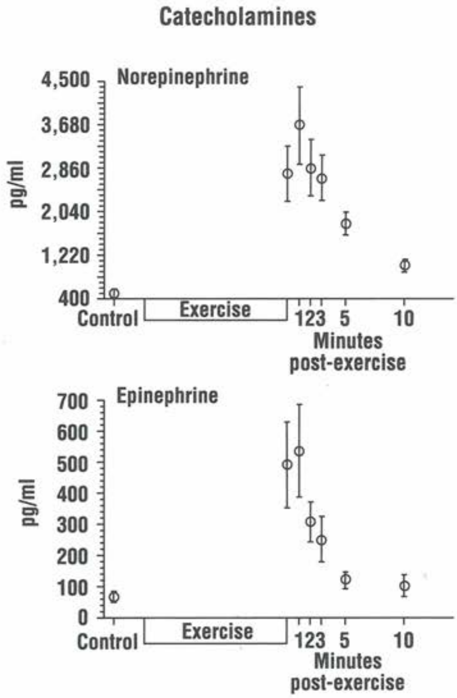

Figure 1. Plasma concentrations of epinephrine (top) and norepinephrine (bottom) during the course of the exercise and recovery periods. Means and standard errors of the mean are shown.

A continuing rise in catecholamine concentrations accompanied by a precipitous fall in plasma K has not been reported before. The plasma K levels in the test subjects fell at a mean rate of 0.54

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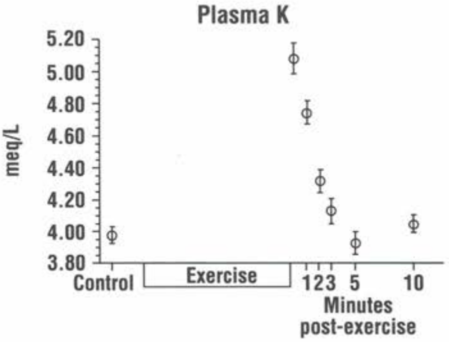

Figure 2. Plasma K concentration during the exercise and recovery period. Means and standard errors are shown.

meq/L/minute. In some individuals the fall was as great as 1.50 meq/L in 2 minutes. During the period of rapidly falling K concentrations, concentrations of the catecholamines continued to rise. These biochemical abnormalities, although present only transiently during the post-exercise period, may contribute to the vulnerability of the metabolically stressed myocardium (the middle and thickest layer of the heart wall) to other arrhythmogenic factors such as coronary insufficiency or ischemia (blood deficiency due to blood vessel obstruction).

If the coronary arteries constricted in response to the sharp fall in K after exercise, the risk of arrhythmia would be elevated in subjects whose coronary blood distribution was already limited by pre-existing disease.

RESEARCH is continuing to determine the possible role of K in reducing risk of "post-exercise peril."

Summary

This combination of biochemical and hormonal factors may contribute to the arrhythmogenic risks imposed by other factors such as myocardial ischemia. It would suggest the consumption of K-rich foods and beverages prior to strenuous exercise, because the body is unable to store K to use during periods of great demand. However, one should use caution when ingesting large amounts of K and do so only under directions of a physician. ■

Mississippi

Effects of Potassium Deficiency on Heart Functions in Animals

THE EFFECTS of moderate, chronic (five days) potassium (K) depletion on cardiac function were assessed in 14 dogs with sufficient K (normokalemic) and 13 with K deficiency (hypokalemic). Plasma K concentrations were significantly lower in the hypokalemic animals. Potassium deficiency produced major negative effects on several indices of mechanical cardiac function during both contraction and relaxation.

The authors suggest that results of the study indicate moderate hypokalemia may not affect the unstressed function of the normal heart, but may severely limit the ability of the heart to respond to stress and exercise. Deleterious effects of hypokalemia would be expected to be most severe in individuals with serious levels of heart disease. Results of this study should help determine whether to correct moderate K depletion and hypokalemia in the large number of human patients with this condition. ■

Source: D. E. Fitzovich, M. Hamaguchi, W. B. Tull and D. B. Young. J. Am. Coll. Cardiol. 18:1,105-1,111. 1991.

Texas Research

Chloride Promotes Wheat Health and Increases Yields

By Travis Miller

Chloride (Cl) is a sometimes misunderstood and controversial element in plant nutrition. In the past, only the potassium (K) in potash (KCl) received attention as an essential nutrient. As a result, in the Great Plains, Canadian Prairies and Southwest U.S. where K soil tests were high, it was felt that KCl was not needed. After years of removal by small grains and other crops, and no Cl fertilization, Cl deficiency is becoming a greater hindrance to wheat yields, as shown in this study.

A POSITIVE RESPONSE of wheat to Cl-bearing fertilizers has been documented in numerous locations in the U.S. and Canada. This response includes a classic nutrient response with a corresponding improvement in leaf color as well as a suppression of fungal diseases.

Improvements in grain yield are attributed to both a classical nutrient response and reduced injury from fungal diseases. In Texas, suppression of leaf rust and septoria leaf blotch have been observed. In other locations, Cl fertility has suppressed crop injury from take-all, tan spot, common root rot, fusarium root rot and stripe rust. The level of suppression of fungal disease and the degree of nutrient response vary with wheat variety, Cl levels in soils and irrigation water, severity of disease infestation and weather conditions.

Chloride Availability

Chloride deficiency is complicated by the mobility of the Cl ion, which is similar to the nitrate ion in solubility and mobility in soils. The lack of Cl-bearing minerals for replenishing this nutrient adds to the problem. Data from Kansas and other central Great Plains states indicate that in most years, fall preplant and/or spring topdress Cl applications are equally effective in suppressing diseases and increasing yields. In years with high winter rainfall, however, spring applied Cl applications are more effective because Cl can be leached out of the rooting zone with high precipitation.

Texas Studies

Due to heavy winter precipitation in the Blacklands and east Texas wheat growing areas, spring application of Cl appears to be more effective than preplant applications in terms of disease suppression and yield improvement. Data in **Table 1** show the effects of spring applied magnesium chloride ($MgCl_2$), ammonium chloride (NH_4Cl), and KCl with varying rates and application methods on wheat yields. Overall, the 40 lb/A Cl rate (either foliar or soil applied) produced an increase of about 8 to 12 bu/A. The 20 lb/A foliar rate of Cl as NH_4Cl also produced an 8 bu/A response.

Increasing rates of Cl from all sources suppressed septoria leaf spot infection. Photographs of the third leaf below the flag leaf were collected on April 13, 1993, at a location in Bosque County, TX. Note **Figures 1, 2 and 3** indicate increasing rates of Cl were effective in lowering the incidence of septoria and that the various

Table 1. Effect of spring applications of Cl sources on wheat yields.

Fertilizer sources	Cl rates, lb/A	Method of application	Grain yield, bu/A
Check	0	—	36
$MgCl_2$	10	Foliar	38
$MgCl_2$	20	Foliar	40
$MgCl_2$	40	Foliar	44
NH_4Cl	20	Foliar	44
NH_4Cl	40	Foliar	45
KCl	40	Soil	45
NH_4Cl	40	Soil	48

Data from Bosque County, TX.

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Cl sources were essentially equal in correcting Cl deficiency.

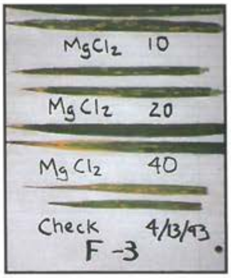


Figure 1. Effects of foliar $MgCl_2$ on septoria leaf spot with 10, 20 and 40 lb/A Cl rates compared to the check.

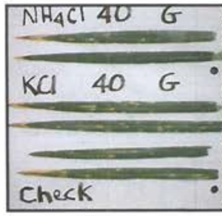


Figure 2. Effects of soil applied NH_4Cl and KCl at 40 lb/A Cl rates compared to the check.

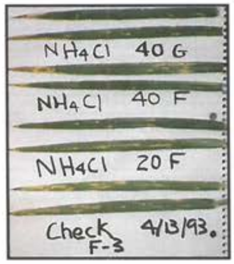


Figure 3. Effects of foliar and soil (G) applied NH_4Cl at 20 and 40 lb/A Cl rates compared to the check.

Conclusions

Texas studies continue to indicate that Cl fertilization on low Cl soils can have significant suppressive effects on fungal leaf diseases of wheat (leaf rust and septoria). Responses vary somewhat with variety, management and growing conditions. Grain yields have been significantly increased as a result of Cl application. Late winter or spring Cl applications appear to be more effective, probably due to leaching of Cl by winter precipitation. ■

RESEARCH NOTES

Texas

Stand Dynamics and Yield Components of Alfalfa as Affected by Phosphorus Fertility

SCIENTISTS at Texas A&M, Beaumont, measured the effects of phosphorus (P) fertilization on alfalfa yield and stand components. The test soil, a Windthorst fine sandy loam, was low in P. Three preplant incorporated rates of P_2O_5 (0, 60 and 120 lb/A) and five annual surface broadcast rates (0, 15, 30, 60 and 120 lb/A) were applied to two field experiments.

Preplant incorporated P increased dry matter yields more efficiently than did broadcast P. Neither plant nor shoot densities were different among treatments. Researchers concluded that yield differences were a function of yield per shoot. Where no P was applied, root mass was concentrated in the upper 8 inches of soil. Where adequate P was available, root mass was distributed throughout the upper 16 to 20 inches. ■

Source: Sanderson, M.A. and R.M. Jones. 1993. Agron. J. 85:241-246.

New Color Slide Program Features Identification of Nutrient Disorders in Sugarcane

THE Potash & Phosphate Institute (PPI) has prepared a color slide set as a companion to the book *Sugarcane Nutrition*, published jointly by PPI, the Potash & Phosphate Institute of Canada (PPIC), and the Foundation for Agronomic Research (FAR) in 1991. The slide set consists of 69 color 35mm slides, with printed script.

The slide set serves as a visual guide to identification of plant nutrient disorders in sugarcane.

The color slide set with script is available at a cost of $40.00 plus shipping. Discounts are available for quantity purchases and for members of PPI, contributors to FAR, and to university and government agencies.

For additional information or to place an order, contact: Circulation Department, PPI, 655 Engineering Drive, Suite 110, Norcross, GA 30092; phone (404) 447-0335, fax (404) 448-0439. ■

North Dakota

Yield Variability Considerations for Spring Wheat Yield Goals

By Lyle Prunty and R. J. Goos

Efficient agriculture requires that management decisions be as site specific as possible. In this article, North Dakota researchers demonstrate that year-to-year variability in site or cropping system yield potential is an important factor for making nitrogen (N) rate decisions.

WHEAT YIELD in the Great Plains is typified by wide year-to-year variations, largely due to climatic factors. These yield variations make it difficult for farmers to evaluate needs for variable crop inputs. Variability in yield has received little attention, but needs to be considered when setting yield goals for N fertilization of spring wheat.

We recently developed a methodology for economic choice of N rate based on average yield, variability of yield, the cost for N, soil test N results, and the price of wheat. Our method is based on wheat response to N fertilizer being a linear-plateau function in any particular year. However, what that plateau will be in the coming season is unknown to the producer when the yield goal and N rate are set.

The N-Budget for Spring Wheat

The N-budget approach, in one form or another, is used by most laboratories to make N fertilizer recommendations for wheat, although the exact approach differs among laboratories. The producer establishes the yield goal and obtains an analysis of the soil for nitrate-N. The fertilizer needed is calculated as the product of yield goal and an N coefficient, less soil nitrate-N. The N coefficient has been determined experimentally from N rate experiments. For spring wheat in the northern Great Plains, the coefficient is about 2.5 lb of N per bushel of expected yield.

Profitability and Yield Goal

We feel that variability should be recognized as an important determinant of profitability, but in the commonly used decision-making schemes, it is not. Nevertheless, many producers take their experience with variability into account by fertilizing for the exceptionally good year. In the process, some set yield goals too high.

Clearly, there are environmental and economic consequences of the N fertilization rate decision. A method for including variability when establishing the yield goal is needed. Our objective was to adapt the linear-plateau production function for this purpose. It is the one most closely associated with the N-budget, yield-goal approach and has been widely used.

The Average Production Function for Spring Wheat

Our method of using the linear-plateau model involves averaging in the variability. As an example, consider three years in which the plateau yield is different (**Figure 1**). We can calculate the average response for these three years and see that we no longer have a simple linear-plateau graph, but rather a graph with three different response slopes, then the plateau (**Figure 1** - dashed line). If we were to produce a similar response graph from 20 or more years of data, it would be a nearly smooth curve.

The authors are with the Department of Soil Science, North Dakota State University, P.O. Box 5638, Fargo, ND 58105. Contribution of the North Dakota Agric. Exp. Stn. Journal no. 2097.

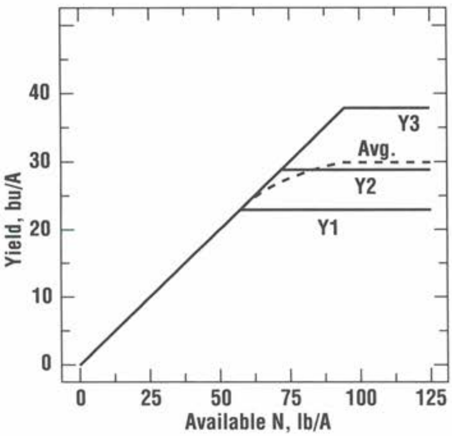


Figure 1. Linear-plateau response for three different years with plateau yields of 23, 29 and 38 bu/A, respectively. Average plateau yield is 30 bu/A. Average response for the three years together is shown by the dashed line.

We calculated the statistical smoothing effect of variability to find the most profitable N fertilization yield goal for spring wheat. To accomplish this, we: 1) used the linear-plateau function for single-year response of spring wheat to available N; 2) defined potential yield; 3) presumed random year-to-year variability in potential yield and calculated potential yield variability from North Dakota yield data; 4) developed the average expected N response function; and 5) found the slope of the N response function and employed it to find the most profitable yield goal.

Our definition of "potential yield" is the yield for a given land unit in a given year when all controllable production inputs (fertilizer, herbicides, etc.) are near "optimal" in terms of maximizing yield. Potential yield often has wide annual variations. This in turn leads to wide variations in the amount of N fertilizer actually needed by a wheat crop to achieve potential yield (**Figure 1**). Potential yield is random and cannot be predicted at the time the fertilization decision is made.

We examined spring wheat yield data from plots under advanced management (fertility, weed control, etc. not limiting) and two rotations at several Branch Experiment Stations in North Dakota (**Table 1**). These yields are in essence "potential yields". Spring wheat yields at the western most branch stations (Williston and Dickinson) show a very high variability in potential yield, especially when planted after cereals or sunflower (recrop). Yields from the stations further to the east (Minot and Carrington) were less variable.

We calculated by statistical techniques the influence of yield variability on most profitable yield for an average yield of 30 bu/A. Our calculations were performed over the range of coefficient of variation (CV) from 5 to 70 percent. (See box for explanation of CV.) The slopes of the response functions were then calculated for the same CVs. Representative curves of slope versus available N are shown in **Figure 2**. The slope tells us the additional wheat produced per added pound of available N.

Data from **Table 1** and slopes as in **Figure 2** were used to find the yield goal that would result in the greatest return for several cost/price situations **(Table 2)**. For other situations we developed a table of average yield multipliers **(Table 3)** that apply for various combinations of CV and cost/price ratio.

Table 1. North Dakota yields of hard red spring wheat in replicated variety or rotation trials.

		Year										
		'80	'81	'82	'83	'84	'85	'86	'87	'88	Mean,	CV,
Site	Rotation	Yield, bu/A									bu/A	%
Dickinson	Fallow	23	44	49	36	43	52	55	33	8	38	40
Dickinson	Recrop	0	14	25	39	27	21	31	9	0	18	74
Williston	Fallow	13	38	50	26	23	12	43	22	6	26	58
Williston	Recrop	1	29	41	26	10	15	31	21	3	20	69
Minot	Fallow	27	39	53	48	52	61	44	35	18	42	32
Minot	Recrop	8	33	48	49	40	54	38	10	8	32	58
Carrington	Fallow	40	38	56	43	55	47	47	44	24	44	22

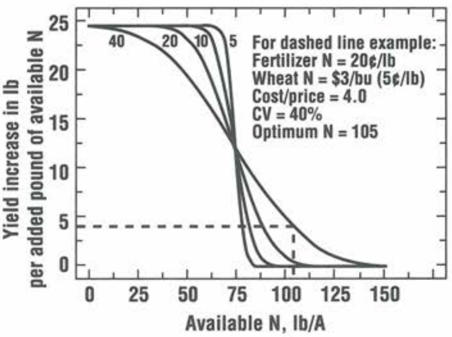


Figure 2. Slope of the expected response to N for several CVs when the average long-term potential yield is 30 bu/A.

Let's now consider specific values based on recent costs and prices. Suppose the applied cost for N fertilizer, including interest charges from purchase to harvest, is 20¢/lb and the price of wheat (expected) is $3.00/bu, or 5¢/lb. Under these conditions, addition of N fertilizer will be profitable as long as 4 lb of wheat or more are produced for each added pound of N. For a CV of 40, the break-even N rate is about 105 lb of available N (**Figure 2**).

At a cost/price ratio of 3.60 (**Table 3**), a simple rule-of-thumb works for finding the most profitable yield goal. It is very close to the average yield plus one standard deviation. **This implies that, as long as the cost/price of 3.60 prevails, a farmer's harvested yield should equal or exceed his fertilization yield goal about 15 years in 100, or about 1 in 6.**

Determining a most-profitable yield-goal by using the multipliers in **Table 3** is straightforward. First, verify that yield values used in the analysis are at the potential yield level. The average yields of **Table 1**, for instance, are from plots that received N fertilizer at a high enough level that it is virtually certain that N was not limiting. A good way for spring wheat farmers to check to see if past yields have been limited by N is to check the protein content records. If protein is greater than 14 percent, (12 percent for winter wheat) N was probably not limiting.

Table 3. Multipliers[1] for calculating most profitable yield goal when average potential yield is known.

CV, %	Cost per lb N / Price per lb wheat 2.4	3.6	4.8	18.0
5	1.07	1.06	1.04	0.97
10	1.13	1.11	1.09	0.93
20	1.26	1.21	1.17	0.87
40	1.51	1.42	1.34	0.73
60	1.77	1.62	1.50	0.60
80	2.03	1.83	1.68	0.46

[1]If cost/price equals 12.0, then the multiplier is 1.00 for all values of CV.

Second, determine the CV and cost/price values. The CV may be calculated or a reasonable estimate may be possible by referring to data from nearby research plots. Calculate the expected cost/price ratio as in the numerical example above. The cost of interest and application should be added to the fertilizer material cost. Third, find the multiplier from the table as determined by CV and cost/price. Finally, multiply the average yield by the multiplier. If the average yield is determined to be less than the potential yield according to the first step, then some rational upward adjustment of the average yield may be considered before applying the multiplier.

Table 2. Most profitable yield goal determined by the point where the cost per pound of additional N fertilizer equals the added income produced by that pound of N.

Location	Rotation	CV, %	Average yield; N not limiting	Cost per lb N/ price per lb wheat 2.4	3.6	4.8	18.0
			---------- Yield, bu/A ----------				
Dickinson	Fallow	40	38	57	54	51	28
Dickinson	Recrop	74	18	35	32	29	9
Williston	Fallow	58	26	46	42	39	16
Williston	Recrop	69	20	38	35	32	11
Minot	Fallow	32	42	58	55	53	34
Minot	Recrop	58	32	57	52	48	19
Carrington	Fallow	22	44	55	53	52	38

Summary

This methodology is practical because it has similarities to the existing yield-goal approach and because necessary data are available or can be estimated. It is crucial to know average potential yield and its variability. Although this paper addresses only the N input, the principles developed here can readily be extended to multiple inputs. For instance, the expected value of yield as a function of N and P could be found under the assumption that in the responsive region to each nutrient, the response slope is uniform each year, but the plateau yield level has a value that is randomly distributed through years with some mean and variance. Future improved predictability of climatic factors could also be included in the methodology. ■

Coefficient of variability (CV) is one way of expressing the variability of data. The CV increases as variability increases and is calculated by dividing the standard deviation by the average for the data set and expressing the result as a percent. Standard deviation (sd) can be determined automatically in most computer spreadsheets or can be calculated by hand as follows.

Example: yields=60, 20, 40, 30, 50 bu/A; 60+20+40+30+50=200; average=40;

$60^2+20^2+40^2+30^2+50^2=9{,}000$

$$\text{sd} = \sqrt{\frac{\text{sum of each squared yield} - \frac{(\text{yield sum})^2}{\text{no. of years}}}{\text{years} - 1}} = \sqrt{\frac{9{,}000 - \frac{200^2}{5}}{5-1}} = \sqrt{\frac{9{,}000 - 8{,}000}{4}} = \sqrt{250} = 15.8$$

New York

Growth, Yield and Quality of Forage Maize under Different Nitrogen Management Practices

STUDIES were conducted to evaluate three corn (maize) hybrids under different sidedress nitrogen (N) rates . . . 0, 50, 125 and 225 lb/A . . . applied at the V4 growth stage. The effect of timing of N fertilization was also evaluated . . . 62.5+62.5 lb/A N at the V4 and V8 growth stages and 67+67+67 lb/A at the V4, V8 and R1 stages.

Yield response to N was curvilinear to rate, with optimum economic yield occurring at rates of 125 to 140 lb/A. Split applications did not increase yields, improve forage quality or decrease residual soil nitrate-N levels compared to single rate applications. Higher N rates did increase residual soil levels in both years.

Researchers pointed out that when farmers apply higher rates of N to forage corn, they must balance potential benefits (higher yields and improved quality) with the potential risk associated with increased residual soil nitrate-N levels. ■

Source: Cox W.J., S. Kalonge, D.J.R. Cherney and W.S. Reid. 1993. Agron. J. 85:341-347.

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

FIVE outstanding graduate students have been announced as the 1993 winners of the "J. Fielding Reed PPI Fellowships" by the Potash & Phosphate Institute (PPI). Grants of $2,000 each are presented to the individuals. All are candidates for either the Master of Science (M.S.) or the Doctor of Philosophy (Ph.D.) degree in soil fertility and related sciences. The 1993 recipients were chosen from nearly 40 applicants who sought the Fellowships. The five are:

- **Thomas W. Bruulsema, Cornell University,** Ithaca, New York;
- **Kevin L. Harner, Purdue University,** West Lafayette, Indiana;
- **David F. Hughes, University of Missouri,** Columbia;
- **Bryan A. Kliewer, North Carolina State University,** Raleigh;
- **Karen Lowell, University of Maryland,** College Park.

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

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

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

Thomas W. Bruulsema was born in Hamilton, Ontario, Canada. He received his B.S. in Agriculture, Honours Program, with Distinction, University of Guelph. He also holds an M.S. degree from that institution and is presently working toward a Ph.D. degree at Cornell University. The objective of his doctoral research is to gain a better understanding of nutrient cycling within the soil-crop system. He will make use of field data, with wheat and corn as test crops, to develop comprehensive, dynamic computer models to better define the relationships between soil nitrogen forms and transformation processes occurring in the soil-crop system. He hopes to use field data and computer models to develop a quantitative soil test for nitrogen, as well as improve tests for nutrients such as phosphorus. Tom is described by one of his Cornell professors as "...being an independent thinker, an extremely capable researcher and someone who clearly can make a mark in his chosen field."


Thomas W. Bruulsema

Kevin L. Harner was born in Bedford, IN. He received his B.S. degree at Purdue University in 1991 and is presently in an M.S. program, also at Purdue. He was chosen as the outstanding senior in agronomy, was the recipient of the Continental Grain scholarship, among others, and was a Distinguished Student seven of his eight undergraduate semesters. His thesis title is "Presidedress Soil Nitrate Test as Basis for Nitrogen Recommendations on Corn in Indiana." The main objectives of his research are to develop correlation and calibration data for the test, based on climatic conditions, soil types and management practices common to Indiana.


Kevin L. Harner

Making use of soil and tissue sampling and a chlorophyll meter, Kevin hopes to develop recommendations based on a broad data base. After completing his M.S. degree, he plans a career in field crop research or agronomic services in the seed or fertilizer industry.

David F. Hughes is a native of Richmond, VA. He earned B.S. and M.S. degrees from Brigham Young University (BYU) where he served as President of the Agronomy Club. Among his honors at BYU was the selection of his research for the outstanding M.S. thesis award by the BYU Sigma Xi Scientific Research Society. He is in the first year of his Ph.D. program at the University of Missouri. His dissertation research will be conducted as a part of the Missouri Management Systems Evaluation Area (MSEA) water quality project. His work will focus on the assessment of the impacts of conventional and alternative systems in Missouri on grain production, nitrogen use efficiency and nitrogen losses over claypan landscapes. Following his graduate study, David hopes to serve as an ASA-CSSA-SSSA Congressional Fellow. He plans a career in soil fertility research and instruction, is interested in international work and, eventually, land grant university administration.

David F. Hughes

Bryan A. Kliewer is working toward his M.S. degree at North Carolina State University. Born in Henderson, NE, he received his B.S. degree from the University of Nebraska-Lincoln. He has won many honors, including the Westinghouse Talent Search award, being one of only 40 students in the U.S. selected who were 'best fitted for promising careers in science.' The title of his thesis is "Response of Soil Denitrification Rates to Water Table Management." The objective of his research is to quantify denitrification losses associated with water table management and to evaluate the time-course behavior of nitrous oxide emissions from poorly drained soils managed with water control structures. Bryan places strong emphasis on scholarship and, as a scholar, plans to pursue further graduate work, then a career in soil fertility and groundwater management and conservation.

Bryan A. Kliewer

Karen Lowell completed her undergraduate study at Allegheny College in Meadville, PA; she is currently in the second year of an M.S. program in Agronomy at the University of Maryland. After her undergraduate studies, she served as a Peace Corps volunteer in Sierra Leone, West Africa. Her work there as an agriculture extension agent led to interests in soil fertility and ways in which research and technology from developed nations can be of use in the developing world. Her thesis is titled "Use of Reduced S to Enhance Bioavailability of P in Phosphate Rock."

Karen Lowell

The Fellowship winners are selected by a committee of PPI scientists. The Fellowships are named in honor of Dr. J. Fielding Reed, retired President of the Institute, who now lives in Athens, GA.

Dr. W.R. Thompson, Jr., PPI Midsouth Director, again served as chairman of the selection committee for the 1993 Fellowships. "The 1993 group had perhaps the highest percentage of top quality applications that we have seen in recent years. The current applicants and winners are among the most deserving in all the years the Fellowships have been awarded, beginning in 1980," he stated. ■

Effects of Boron on Seedling Establishment of Annual Legumes

By G.R. Smith, V.A. Haby, C.L. Gilbert and I.J. Pemberton

Texas research shows that supplemental boron (B) on deficient soils significantly increases legume root development and improves seedling establishment probabilities.

WINTER-ANNUAL CLOVERS are often overseeded on warm-season perennial grass sods for grazing in east Texas. Establishment, at initial planting or increasing stand by natural reseeding, is a major management problem when using these legumes. Soils in the east Texas timberlands are usually sandy and acidic with low native fertility.

Phosphorus (P) and potassium (K) fertilization and liming are generally necessary for annual clover forage production. Boron fertilization has been recommended, but has not been widely used in forage fertilization programs. Field experiments have shown improved reseeding of annual clover stands when B deficiencies were corrected.

Greenhouse Studies

In the greenhouse, B was mixed with soil in individual pots at the rate of 0, 1.5 or 3.0 lb B/A with Mt. Barker subterranean clover seed. Plants were harvested at 2, 3 or 4 weeks. Boron fertilizer significantly increased root, and to a lesser degree, shoot dry weights of seedlings when compared to unfertilized plants. These positive effects on growth were evident when plants were three weeks old (see photo next page).

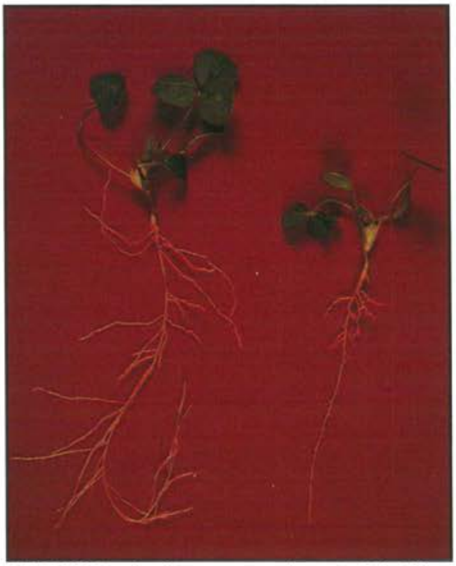
At four weeks, root dry weights of plants fertilized with 1.5 or 3.0 lb B/A were nearly twice that of unfertilized controls. Shoot dry weights at four weeks were 14 and 20 percent greater for plants fertilized with 1.5 or 3.0 lb B/A, respectively, than plants which received no B (**Figure 1**).

Figure 1. Average shoot dry weight at 2,3 and 4 weeks of growth as affected by boron rates.

The increased root mass was due to increases in taproot length and number and size of lateral roots. Taproot lengths were already significantly longer at two weeks for B fertilized plants. After four weeks, this difference was amplified (**Figure 2**). Taproots of unfertilized plants grew an average of only 0.4 inches in two weeks, while those of plants receiving 1.5 or 3.0 lb B/A grew 2.6 and 2.7 inches, respectively. The total number of lateral roots was greater in treatments receiving B than in no B controls. A similar effect was observed for the number of lateral roots over 0.4 inches. In most cases, the 3.0 lb B/A rate caused a slight, but insignificant, growth depression of the subclover seedlings.

Plants which had not received B exhibited typical B deficiency symptoms: stunting of growth at the apical meristem and wrinkled, thicker, bluish-green leaves. Most seedlings had not progressed beyond the cotyledonary stage. Stunted root growth was evident as well.

G.R. Smith is Associate Professor, Legume Breeding; V.A. Haby is Professor, Soils; C.L. Gilbert is Technician; I.J. Pemberton is Research Assistant, all with Texas Agricultural Experiment Station, Overton.



RESPONSE of subterranean clover to B is illustrated with these seedlings, 3 weeks after planting. Plant at left received 1.5 lb/A, while plant at right received no B.

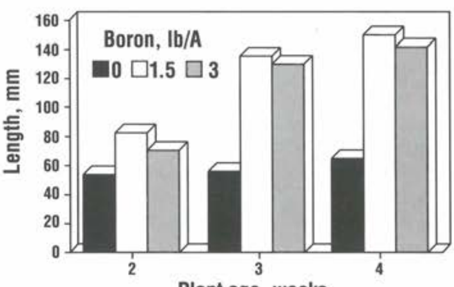


Figure 2. Taproot length at 2, 3 and 4 weeks as affected by B rates.

In a second experiment, B was mixed with the soil on a soil weight basis at the rate of 0, 1.0, 2.0 and 3.0 lb B/A. Legume varieties used included Dixie crimson, Yuchi arrowleaf, common ball, Bigbee berseem, H-18 rose, Mt. Barker subterranean clovers and hairy vetch. Measurements taken after four weeks were root length, shoot and root dry matter yield, total number of lateral roots, number of lateral roots over 0.4 inches, and number of lateral roots over 1.2 inches.

Boron fertilizer, whether applied at 1.0, 2.0 or 3.0 lb/A, significantly increased some aspect of root growth compared to unfertilized controls for all clover species tested. Hairy vetch did not exhibit enhanced root growth. All clovers possessed longer roots and more lateral roots longer than 1.2 inches when fertilized with B. Except for subterranean and rose clovers, all clovers fertilized with B had a greater number of total lateral roots.

Field Studies

In a third experiment, B was applied at 1 and 2 lb/A on three different field sites. Soil samples were taken 15 days before and after B application and at monthly intervals for five months. Sample depths include 0-6, 6-12, 12-24, and 24-36 inches. Preliminary analysis of these data indicates that a 2 lb/A B rate under field conditions provides marginal correction of a B deficiency on sandy soils. Two lb B/A increased soil B from 0.25 parts per million (ppm) to 0.41 ppm at the 0-6 inch sample depth and from 0.1 ppm to 0.36 ppm at the 6-12 inch sample depth.

Application

Our studies show that B is crucial for annual clover seedling establishment, growth and survival. Boron at 1.5 lb/A under greenhouse conditions resulted in dramatically larger plants when water supply was adequate. Plants fertilized with B were also more drought tolerant than unfertilized plants. The deficient native soil B level of less than 0.3 ppm available B was corrected to 0.8-1.0 ppm B by addition of 1.5 lb B/A in the greenhouse studies. Under field conditions, more than 2 lb B/A may be required to correct soil B deficiency on sandy soils.

More research is needed to determine the best method to deliver the required B to the clover seedlings. Annual clover forage production depends on successful seedling establishment. Correcting soil B deficiency before planting will help ensure greater seedling survival under drought conditions and improve early seedling growth and establishment. ■

Boron Improves Clover Production

By V.A. Haby, G.R. Smith, J.N. Pratt, J.R. Brown and J.L. Sanders

Recognizing deficiency symptoms may help diagnose boron (B) as a limiting factor in clover production. The descriptions and photos in this article represent conditions over a widespread area of the U.S.

BORON deficiencies occur throughout North America, and responses to B fertilization of alfalfa, soybeans and other crops have been documented in many areas. During the recent years, B deficiencies have been noted with greater frequency. There are several reasons why this may be occurring:

- Heavier than normal rainfall has occurred in many clover growing areas. Boron is a mobile nutrient which can be leached out of the root zone.
- Higher yielding forage crops have removed greater quantities of B.
- Organic matter is an important source of B. Spring temperatures have been cooler than normal when clover is at its maximum growth rate. Cool weather slows organic matter decomposition which, in turn, slows the release of B.
- Boron is a micronutrient that becomes less available as the soil pH is increased.
- Clover production is highest where soil pH is in the slightly acid to neutral range (6.0 to 7.0). Many farmers and ranchers on acid soils have used lime to increase production. Liming acid soils, however, can interfere with B availability. Research has shown that 1 to 2 lb/A B fertilization is required, depending on the grade and amount of limestone applied.

KENSTAR red clover shown here has leaf reddening and suppressed flower production from B deficiency in Missouri.

Figure 1 shows subterranean clover response to applied nutrients in Texas. The clover was most responsive to added phosphorus (P). Boron application up to 2 lb/A increased clover growth up to 65 percent over the untreated check. This study showed that P and B had the greatest potential to increase clover growth in many east Texas soils.

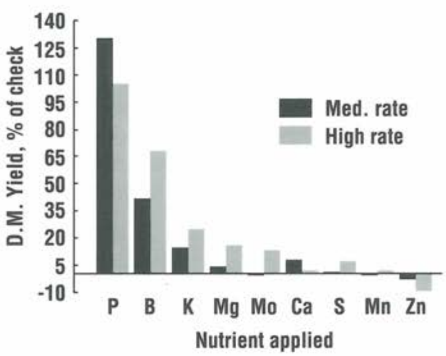


Figure 1. Nutrient effects on subterranean clover.

V.A. Haby is Professor, Soils, and G.R. Smith is Associate Professor, Legume Breeding, Texas Agricultural Experiment Station, Overton. J.N. Pratt is Extension Forage Specialist, Emeritus, Texas Agric. Ext. Service, College Station. J.R. Brown is Professor, Soil Science, University of Missouri, Columbia. J.L. Sanders is Great Plains/Southwest Director, PPI, Stanley, KS.

BORON deficiency of arrowleaf clover may appear as poor root growth (at left) and reddish colored, thick, leathery leaves as shown at right (Texas).

Boron Deficiency Symptoms of Clover

Boron deficiencies are rarely exhibited over an entire field, with the exception of recently limed soils where the entire field may show symptoms. Some typical symptoms are described here.

Roots: Poor root growth, especially on acid soils

Leaves: Thick, leathery
Red margin can occur on newest growth
Entire leaf can turn orange-red and/or pale green
Symptoms usually exhibited at flowering stage when B demand is highest

Flowers: Uneven flowering
Reduced number and size of seed heads
Seed heads may be suppressed in newest foliage growth
Reduced seed viability and reseeding ability

Conclusions

Boron deficiency may be a limiting factor in forage legume yields in many areas. Be aware of B deficiency symptoms as a diagnostic tool, but use soil testing and plant analysis to predict where supplemental B is needed before symptoms appear . . . and production suffers. ■

WHITE CLOVER shown at left is exhibiting B deficiency symptoms in the form of orange-red and pale green leaves. White clover B deficiency symptoms also include red leaf margins, leather leaf texture and poor seed head development, shown at right (Kansas).

Evaluation of Surfactants in Foliar Feeding Cotton with Potassium Nitrate

By D.D. Howard, P.E. Hoskinson and P.W. Brawley

In this experiment, foliar applications of potassium (K) to cotton, at a rate of 10 lb/A potassium nitrate (KNO_3) and with a surfactant, increased petiole and leaf K concentrations. Applying KNO_3 with a surfactant to increase plant K uptake would be beneficial during periods of restricted K uptake. No yield response to foliar K was observed in 1991, the initial year of the study.

ARKANSAS RESEARCH has shown foliar K applications to a fast-fruiting cotton variety increased yield and improved fiber quality. However, many questions concerning the influence of fertilizer source, application rate and timing, soil and climatic conditions on yield and fiber quality remain. Investigations have been initiated in most of the cotton-producing states to evaluate K uptake from foliar KNO_3 applications over a wide range of soil and climatic conditions. The research reported here was initiated to evaluate the influence of surfactants on K uptake from foliar-applied KNO_3.

Procedure

A field experiment was initiated in 1991 at the West Tennessee Experiment Station on a Memphis-Loring-Calloway soil complex testing high in Mehlich I extractable K. The cultivar "DPL-50" was no-till planted on May 15. Plots were fertilized immediately after planting by broadcasting 80-60-60 lb/A of nitrogen (N), P_2O_5 and K_2O, respectively. Plots were irrigated July 18 (1.28 inches), August 6 (1.0 inch), and August 19 (0.8 inch). All recommended production practices were utilized in establishing, growing and harvesting the crop.

Six foliar treatments were initiated on July 29, two weeks after 50 percent of the plants flowered and repeated on two-week intervals for a total of four applications. These treatments were: check; 10 lb/A KNO_3 applied in water; 10 lb/A KNO_3 applied with a surfactant (Penetrator Plus or X-77); and 5 lb/A KNO_3 applied with a surfactant. Foliar treatments were applied in water at 10 gal/A rate. Surfactants were applied at labelled rates.

Cotton leaves and petioles were collected 1, 3, 7 and 14 days after each of the first three foliar applications. A defoliant was applied before the 14-day sample of the 4th application could be collected. Twenty mature leaves, generally the 4th from the terminal, were sampled for each treatment.

Results

Yield. Cotton yields were unaffected by foliar K applications. Sufficient K was supplied by the soil, making foliar applications unnecessary for increasing yields. Lint yields ranged from 840 to 1,092 lb/A.

Leaf K concentrations. Leaf K concentrations were affected by a foliar by spray period interaction. Potassium was applied each spray period. The biochemical activity of the plant probably changed with time, resulting in the interaction. Effects of foliar applications are shown in **Table 1**.

Leaf K concentrations were unaffected by treatments applied two weeks after bloom. Leaf K decreased from 1.33 to 1.19 percent three days following application and increased to 1.25 percent seven days after application, with no additional

The authors are Professor, Professor Emeritus, and Research Assistant, respectively, West Tennessee Experiment Station, Jackson, TN 38305.

Table 1. Leaf K concentrations by spray period as affected by treatment and sampling date.

Surfactant	KNO_3, lb/A	Percent K concentration Weeks after bloom: 2	4	6	8
None (Check)	0	1.31	1.25	0.97	1.15
None (Water)	10	1.14	1.32	0.99	1.20
Penetrator Plus	10	1.37	1.53	1.29	1.36
X-77	10	1.29	1.39	1.18	1.36
Penetrator Plus	5	1.25	1.42	1.11	1.16
X-77	5	1.20	1.39	1.09	1.27
L.S.D. (0.05)		NS	0.13	0.16	0.12
Days after spraying					
1		1.33	1.46	1.36	1.22
3		1.19	1.45	1.04	1.31
7		1.25	1.34	1.01	1.22
14		1.27	1.28	1.00	
L.S.D. (0.05)		0.06	0.11	0.27	NS

change by day 14. Increased leaf K concentrations seven days after application may have coincided with the 1-inch irrigation and rainfall between the 3- and 7-day sampling periods.

Applying 5 or 10 lb/A KNO_3 with a surfactant four weeks after bloom increased leaf K percentage when compared with the check. Applying 10 lb/A KNO_3 with Penetrator Plus increased leaf K when compared with 10 lb/A KNO_3 applied in water. Leaf K decreased between 3- and 14-day sample periods.

Leaf K was increased by applying 10 lb/A KNO_3 with a surfactant six weeks after bloom when compared with the check or applying 10 lb/A KNO_3 in water. Applying 5 lb/A KNO_3 with a surfactant or 10 lb/A with water did not increase leaf K when compared with the check. Leaf K decreased after the first sampling date with no additional change after the 3-day sample period.

Applying 10 lb/A KNO_3 with surfactant eight weeks after bloom increased leaf K when compared with the check or applying 10 lb/A KNO_3 in water. Applying 10 lb/A KNO_3 in water did not affect leaf K when compared with the check.

Petiole K concentrations. Petiole K concentrations were affected by a treatment by spray period interaction (**Table 2**). Applying 10 lb/A KNO_3 with Penetrator Plus two weeks after bloom increased petiole K percentage when compared with applying 10 lb/A KNO_3 in water. Petiole K levels were not increased by other treatments when compared with the check.

Table 2. Petiole K concentrations by spray period as affected by treatment and sampling date.

Surfactant	KNO_3, lb/A	Percent K concentration Weeks after bloom: 2	4	6	8
None (Check)	0	2.86	2.56	2.38	2.52
None (Water)	10	2.55	2.49	2.37	2.33
Penetrator Plus	10	3.17	3.24	3.02	3.02
X-77	10	2.82	2.73	2.82	2.90
Penetrator Plus	5	2.79	2.81	2.65	2.63
X-77	5	2.60	2.78	2.77	2.69
L.S.D. (0.05)		0.34	0.28	0.34	0.33
Days after spraying					
1		2.86	2.68	2.73	2.76
3		2.80	2.99	2.74	2.69
7		2.76	2.58	2.57	2.60
14		2.77	2.83	2.63	
L.S.D. (0.05)		NS	0.22	NS	NS

Petiole K was increased by applying 10 lb/A KNO_3 with Penetrator Plus four weeks after bloom when compared with other treatments. Petiole K was unaffected by applying 5 lb/A KNO_3 with a surfactant or applying 10 lb/A KNO_3 in water.

Petiole K levels were higher six weeks after bloom from applying 10 lb/A KNO_3 with surfactant or 5 lb/A KNO_3 with X-77 when compared with either the check or 10 lb/A KNO_3 applied in water.

Petiole K concentrations were greater eight weeks after bloom for applying 10 lb/A KNO_3 with Penetrator Plus when compared with other treatments, except applying 10 lb/A KNO_3 with X-77. Applying 10 lb/A KNO_3 with X-77 increased petiole K concentrations when compared with the check or 10 lb/A KNO_3 in water.

Discussion

Caution must be exerted when interpreting one-year foliar treatment data

(continued on page 25)

Forage Legumes Respond to Lime and Phosphorus

By B.C. Darst, W.R. Thompson, Jr. and J.T. Touchton

With increased emphasis being placed on environmental protection, forage legumes are receiving more attention, both as cash crops and to provide nitrogen (N) for other crops in the rotation. This review of two Alabama studies illustrates the importance of soil pH, liming, phosphorus (P) and potassium (K) on the yield and production of two common annual forage legumes grown in the southeastern U.S.

CROP PRODUCTION in the U.S. relies heavily on the use of commercially produced N fertilizers. About two-thirds of all N fertilizer used on agricultural crops in this country is commercially produced. Forage legumes, properly managed, offer an alternative N source which can satisfy the needs of the legume itself and provide additional N for other crops in the rotation. Two keys to successful forage legume production are proper soil pH and soil fertility.

In an Alabama study, crimson clover was fall seeded after cotton in a three-year rotation of cotton, corn and soybeans, then turned under as green manure ahead of corn. Soil from the experiment was also planted with crimson clover in a greenhouse study. Initial soil pH was 5.0.

Table 1 shows the influence of liming, P and K on the relative yield, N content and production and effectiveness of N-fixing bacteria (Rhizobia).

Table 1. Acid pH and P and K deficiencies limit crimson clover production.

Treatment	Relative yield, %	Relative N content, %	Effective Rhizobia in the soil, %
P deficient	42	35	68
K deficient	77	81	92
Strongly acid	54	45	92
Lime, P, K	100	100	90

Soil acidity limited both growth and N content of forage tissue to about half that of clover grown in a soil which had been limed and supplied with adequate fertility. Most of the plants grown without lime did not develop nodules, were stunted and chlorotic. Phosphorus deficiency had the greatest negative effect on crop growth, N content and effective Rhizobia population, followed by soil acidity and K deficiency.

In another study, Alabama researchers measured the effects of lime and P on the yield and N production of Dixie crimson and Yuchi arrowleaf clovers. Relative yields are shown in **Table 2**. The 250 lb/A P_2O_5 rate of fertilization significantly increased yields for both species, while the 500 lb/A rate produced no further benefit. Lime also increased yields, but to a lesser extent. Initial soil pH was 5.0, and soil P was very low prior to fertilization.

Table 2. Lime and P increase the yields of crimson and arrowleaf clovers.

P_2O_5 rate, lb/A	Relative yield, %			
	Crimson clover		Arrowleaf clover	
	No lime	Lime	No lime	Lime
0	42	39	14	28
250	72	100	95	100
500	80	90	92	99

Table 3 shows total N production for the two clover species. The percent tissue N at

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CRIMSON CLOVER is a popular legume among cattlemen in the southeastern U.S., although many do not give adequate attention to its nutritional requirements for economic production.

Table 3. Lime and P increase total N production by crimson and arrowleaf clovers.

	Total N production, lb/A			
P_2O_5 rate,	Crimson clover		Arrowleaf clover	
lb/A	No lime	Lime	No lime	Lime
0	40	26	16	40
250	61	100	136	136
500	66	78	110	142

maturity was multiplied by total dry matter production to arrive at the values shown in the table. Nitrogen production for each species increased slightly with liming, but was dramatically increased by P fertilization. Again, the best treatment was the 250 lb/A P_2O_5 rate. Differences in N production were due to effects of yield and Rhizobia nodulation, not N tissue concentration.

The results of these two Alabama studies show the critical importance of good fertilizer management and liming practices on the economic production of forage legumes. They illustrate the point that there is no 'free ride' for the farmer who is looking for ways to save on his or her fertilizer N bill by including legumes in the crop rotation. Legumes require sound management, just as do other crops. Anything less will result in uneconomical production and can increase the potential for damage to the environment. ■

(Foliar Feeding . . . from page 23)

that did not increase yield. However, it would appear that increasing leaf and petiole K concentrations in a non-deficient situation would make these observations even more notable. Petiole K concentrations determined 4 and 6 weeks after bloom were 2.56 and 2.38 percent, respectively, which are higher than levels reported to be critical in the Arkansas research.

Potassium moves from the leaves through the petioles to points of demand within the plant, thus allowing leaf K concentrations to change more than the petiole. Petiole K concentrations were about double the leaf K concentrations. Petiole K decreased from 2.2 to 2.0 times leaf K as the number of weeks after bloom increased from two to six. But after eight weeks the ratio of petiole to leaf increased to 2.4. Leaf K concentrations decreased rather sharply six weeks after bloom, indicating a greater demand by the plant than the previous sample period. This decrease was also reflected by the petiole data.

Apparently, the critical time for applying K to these plots was six weeks after bloom. By August 26, six weeks after bloom, the cotton plant enters the maturation stage. During this time, increases in seed size, micronaire, and probably fiber strength also occur. In addition, drought conditions that are common during this period may have restricted root uptake of K since plots had not received irrigation or rainfall since August 19 and many leaves were approaching senescence.

Foliar application of 10 lb/A KNO_3 with either Penetrator Plus or X-77 increased leaf and petiole K concentrations. Applying 10 lb/A KNO_3 with Penetrator Plus consistently resulted in the highest leaf and petiole K concentrations. Applying KNO_3 with a surfactant to increase plant K uptake would be beneficial during periods of restricted soil uptake. Applying lower KNO_3 rates could reduce the possibility of leaf burn during drought stress. ■

Immobilization and Uptake of Ammonium and Nitrate Nitrogen in Starter Fertilizer

By D.D. Francis, J.W. Doran and R.D. Lohry

Studies using starter fertilizers tagged with $^{15}NH_4NO_3$ or $NH_4{}^{15}NO_3$ indicated that nitrate nitrogen (NO_3-N) in the starter was leached from corn seedling root zone before it could be fully utilized. The presence of dicyandiamide (DCD) in a fluid starter maintained more nitrogen (N) in the NH_4 form, resulting in greater crop N uptake and more microbial immobilization of fertilizer N.

CORN PRODUCERS often supplement their regular fertilizer program by using a starter fertilizer placed near the seed at planting. The intent is to make plants more vigorous during cool spring weather by stimulating early root and shoot growth. Higher N concentration starters are typically produced by adding urea ammonium nitrate (UAN) solution to mixed grade fluid fertilizers. Identifying the fate of ammonium (NH_4) and nitrate (NO_3) in high N starters would aid in determining what formulation is best.

The question of which form of N . . . NH_4 or NO_3 . . . to supply to plants at specific growth stages is an interesting one. Each form has characteristic advantages and disadvantages. A theoretical advantage of NH_4-N is that energy would not have to be expended in reducing NO_3-N to the amide form for assimilation in the developing plant. It has also been determined that NH_4-N is more likely to enhance the uptake of phosphorus (P) in young plants. Disadvantages of NH_4-N in starters include higher susceptibility to immobilization by soil microorganisms, greater potential for soil acidification and the potential for chemical and/or clay fixation in some soils.

In moist, well-drained soils, NH_4 is usually nitrified rapidly to NO_3. Nitrate is carried readily to plant roots by mass flow, but under wet conditions is subject to loss by leaching and denitrification.

Cultural practices affect N availability, crop use and the fate of unabsorbed N. High concentrations of crop residue in surface soil will likely increase the portion of starter N immobilized by soil microorganisms.

Nebraska Research

A study was designed to compare plant uptake and microbial immobilization of NH_4-N and NO_3-N in starter fertilizer for continuous corn. Studies were conducted on a Janude sandy loam and a Hord silt loam. Both are deep, well drained soils with moderately rapid permeability and good water holding capacity.

Single tagged $^{15}NH_4NO_3$ or $NH_4{}^{15}NO_3$ was added to formulated starter fertilizers to trace the N applied in the starter. The starter contained N, P_2O_5, K_2O, sulfur (S) and zinc (Zn) with a composition of 12-12-3-2.5-0.4 the first year and 14-14-3-2-0.6 the second year. The starter supplied 20 lb N/A. Because of leaching losses and low plant ^{15}N recovery the first year, the nitrification inhibitor DCD was included in the starter the second year. In this case, 4 percent of starter-NH_4-N was DCD-N. Tagged starter was diluted with water (2:1) to aid in uniform delivery and was injected with a calibrated hand

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syringe at a depth of 3 inches, at 3-inch intervals, immediately after planting and 2 inches from the row on the center two rows of each plot.

Plant and soil samples were collected at the V3 and V8 growth stages (about 4 and 7 weeks after planting). Soil was sampled at depth increments of 0-2, 2-5 and 5-12 inches to give samples from above, in and below the zone of injection.

Nitrogen Movement

Plant samples collected at the V3 growth stage the first year indicated a much higher apparent plant utilization of starter NH_4 than NO_3 **(Table 1)**. One possible explanation is preferential uptake, but this probably was not the main cause in this case. Spring rainfall had been below normal and, to insure uniform germination and a good stand, the cooperator applied approximately 2 inches of irrigation water through a sprinkler system about five days after planting. Approximately four days later the plots received an additional 1.2 inches of rain. Irrigation and rainfall totaled nearly 5 inches between planting and first sampling.

Soil analysis indicated that this moisture apparently had moved most of the $^{15}NO_3$ out of the top 12 inches of soil by the first sampling date (**Table 2**). Only 1 percent of the starter N applied as NO_3 was found as KCl-extractable inorganic N above the 5-inch depth the first year, compared to approximately 20 percent for $^{15}NH_4$ at the V3 growth stage. The plots were located on a well drained sandy loam soil, which would suggest a low potential for denitrification. In addition, isotope enrichment at the 5- to 12-inch depth showed that $^{15}NH_4$ had also moved downward. Isotope analysis indicated that practically all of the fertilizer $^{15}NH_4$ had either been nitrified or immobilized by the first sampling date, and most likely moved downward as $^{15}NO_3$.

Increased plant utilization of ^{15}N by the V8 growth stage the first year suggested that the roots were beginning to intercept the leached ^{15}N (**Table 1**). Similar utilization of ^{15}N, whether applied as NO_3 or NH_4, between the V3 and V8 growth stages would be expected if both sources were mainly in the same form (NO_3) with similar positional availability in the expanding root zone. This indicated that N applied as NO_3 did not leach much further than that originally applied as NH_4.

Nitrogen Immobilization

The maximum amount of fertilizer ^{15}N in the microbial biomass can be estimated by subtracting the fertilizer-derived ^{15}N in the soil inorganic N pool from the total fertilizer-derived ^{15}N in the soil. Biomass ^{15}N would not exceed this difference value because any ^{15}N fixed by soil clays also would be included in the difference between total soil ^{15}N and inorganic ^{15}N. First year data indicated greater microbial immobilization of NH_4-N despite rapid nitrification (**Table 3**).

Nitrification Inhibitor Effects

Because much of the ^{15}N was leached below the root zone of the V3 plants the first year, the second year of the study

Table 1. Percent utilization (standard deviation in parenthesis) by corn of ^{15}N applied in a starter fertilizer.

	Year 1		Year 2			
Growth stage	$^{15}NO_3$	$^{15}NH_4$	$^{15}NO_3$	$^{15}NO_3$ (+ DCD)[1]	$^{15}NH_4$	$^{15}NH_4$ (+ DCD)
	% Utilization of ^{15}N[2]					
V3	1.0 (0.7)	11.1 (2.4)	2.9 (1.9)	4.4 (2.0)	8.4 (2.2)	16.3 (1.8)
V8	10.1 (4.7)	20.6 (7.2)	51.5 (6.9)	49.7 (8.6)	61.2 (5.2)	62.6 (1.8)

[1]DCD = Dicyandiamide
[2]Percent utilization of ^{15}N = percent of fertilizer ^{15}N recovered in entire above-ground material.

Table 2. Percent of starter fertilizer ^{15}N (standard deviation in parenthesis) recovered in the top 12 inches of soil at the V3 sampling date.

Year	Treatment	Soil depth increment, inches	Soil N fraction: Total ^{15}N	KCl extractable ^{15}N: NO_3-N	KCl extractable ^{15}N: NH_4-N
			------	% ------	------
Year 1	$^{15}NO_3$	0-2	1.0 (0.1)	0.3 (0.3)	0.0 (0.0)
		2-5	1.6 (1.1)	0.8 (0.7)	0.0 (0.0)
		5-12	12.8 (1.4)	11.4 (1.4)	0.0 (0.0)
	$^{15}NH_4$	0-2	8.0 (3.5)	3.0 (2.0)	0.0 (0.0)
		2-5	26.6 (9.9)	16.6 (10.5)	0.4 (0.4)
		5-12	27.7 (6.0)	24.9 (4.8)	0.1 (0.1)
Year 2	$^{15}NO_3$	0-2	1.2 (0.4)	0.4 (0.3)	0.0 (0.0)
		2-5	2.6 (2.4)	1.9 (1.6)	0.0 (0.0)
		5-12	9.2 (4.9)	7.7 (4.5)	0.0 (0.0)
	$^{15}NH_4$	0-2	6.5 (3.3)	3.7 (2.6)	0.0 (0.0)
		2-5	12.4 (4.5)	10.3 (5.7)	0.1 (0.1)
		5-12	17.3 (2.9)	15.7 (3.3)	0.0 (0.0)
	$^{15}NO_3$ + DCD	0-2	1.8 (0.5)	0.5 (0.3)	0.0 (0.0)
		2-5	2.7 (1.1)	1.6 (1.0)	0.2 (0.1)
		5-12	11.4 (2.8)	9.9 (2.8)	0.1 (0.1)
	$^{15}NH_4$ + DCD	0-2	23.2 (9.9)	9.8 (2.0)	2.8 (2.0)
		2-5	32.3 (8.3)	13.4 (2.1)	8.4 (2.2)
		5-12	13.7 (4.1)	12.8 (3.7)	0.1 (0.1)

included the nitrification inhibitor, DCD, with both $^{15}NH_4$ and $^{15}NO_3$ treatments. DCD is an effective nitrification inhibitor for approximately 6 to 10 weeks. It is thought to interfere with the respiration of *Nitrosomonas* genus of bacteria, which are primarily responsible for the first step in nitrification.

At the V3 growth stage in the second year, utilization of fertilizer $^{15}NH_4$ by corn was more than twice that of $^{15}NO_3$ (**Table 1**). The addition of DCD approximately doubled the utilization of fertilizer $^{15}NH_4$ at this growth stage. Without considering other information, plant N uptake data would suggest preferential uptake. However, excess moisture (4 inches of rainfall before emergence and over 7 inches before sampling) removed over 95 percent of the $^{15}NO_3$ out of the top 5 inches of soil by the V3 growth stage (**Table 2**). Although more than half of the $^{15}NH_4$ without DCD could not be accounted for in the above-ground corn tissue or in soil to 12 inches by this date, nearly 15 percent was still available in the $^{15}NO_3$ form in the top 5 inches. With $^{15}NH_4$+DCD, the highest proportion of ^{15}N was still available to the plants, with nearly one-half the applied amount in inorganic forms in the top 12 inches of soil four weeks after planting.

Large increases in crop utilization of ^{15}N at the V8 growth stage for all treatments in year 2 indicate (again) that much of the starter N that had leached out of the upper 12 inches of soil was within the crop root zone by the V8 stage. Although crop utilization of ^{15}N at V8 was much higher in year 2 than year 1, similar increases occurred both years between the V3 and V8 growth stages, whether the ^{15}N was

Table 3. Estimated fertilizer ^{15}N (standard deviation in parenthesis) recovered in soil biomass at the V3 sampling date.

Year	Treatment	Soil depth increment, in.	Method of estimation: Difference[1]	Method of estimation: Incubation[2]
			------	% ------
Year 1	$^{15}NO_3$	0-2	0.7 (0.3)	0.3 (0.1)
		2-5	0.8 (0.5)	0.7 (0.5)
	$^{15}NH_4$	0-2	5.0 (1.5)	3.3 (2.3)
		2-5	9.6 (3.0)	7.7 (4.0)
Year 2	$^{15}NO_3$	0-2	0.8 (0.2)	0.5 (0.2)
		2-5	0.9 (0.6)	0.6 (0.3)
	$^{15}NH_4$	0-2	2.7 (0.8)	3.0 (1.4)
		2-5	2.0 (1.5)	1.8 (0.6)
	$^{15}NO_3$ + DCD	0-2	1.2 (0.3)	1.1 (0.2)
		2-5	1.1 (0.4)	1.4 (0.6)
	$^{15}NH_4$ + DCD	0-2	10.6 (6.0)	9.3 (4.3)
		2-5	13.3 (3.6)	14.8 (6.2)

[1]Difference + Total percent fertilizer ^{15}N found in soil less percent fertilizer ^{15}N found in KCl extractable inorganic pool.
[2]Derived using the Shen et al. method for determining biomass N.

applied as NO_3 or NH_4. This would be expected if the ^{15}N was mainly in the same form (NO_3) with similar positional availability between V3 and V8.

In addition to increasing plant uptake, DCD also enabled more fertilizer ^{15}N to be taken up by the microbial biomass (**Table 3**), probably by maintaining fertilizer N in the NH_4 form.

Conclusions

Efficient use of starter fertilizer N by young plants is dependent upon keeping the N positionally available. Nitrate-N in starter fertilizer can be readily leached out of the rooting zone of permeable soils before it can be utilized by young plants, although it may be recovered later by older plants. Application of starter N as NH_4 without a nitrification inhibitor only slightly improved plant N uptake. For the soils used in this study, nitrification of NH_4 followed by leaching was a greater barrier than microbial immobilization to the efficient use of starter NH_4.

DCD significantly increased crop utilization and microbial immobilization of starter NH_4. This is probably related to DCD maintaining more starter fertilizer N in the NH_4 form and maintaining positional availability. Under moderate leaching conditions, it may be advantageous to add a nitrification inhibitor to starters to ensure that fertilizer N remains positionally available to young corn plants. ■

ASA, CSSA, SSSA Publish *Soil Specific Crop Management–A Workshop In Research And Development Issues*

HISTORIC agronomic practices have been developed with the farm or field as the area of management. The advent of soil conservation began to focus soil management on topographic and soil specific features. Even so, agronomic practices and recommendations have largely been made on a field basis rather than on soil specific properties that might influence tillage, seeding, fertilizing and weed control practices. The near completion of detailed soil surveys nationwide, particularly in the intensive agricultural areas, has provided a database of great magnitude. The advent of computer processed spatial data together with geostatistical analysis enables the display of those soil, hydrologic and micro-climate features relevant to agronomic practices. With the further development of positioning systems suitable to on-site application, the capability now exists, or can be feasibly developed, to deliver real-time, real-space changes in almost any agronomic procedures.

This Soil Specific Crop Management workshop consisted of invited papers on the topics of soil resources variability, managing variability, engineering technology, profitability, environment and technology transfer. They were followed by several invited presentations detailing current research and development in each of the six areas.

Soil Specific Crop Management–A Workshop in Research and Development Issues. P.C. Robert, R.H. Rust, and W.E. Larson, editors. Published by the American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America. Softcover, 406 pages, 1993. ISBN 0-89118-116-4. Price: $20.00.

All payments must be in U.S. funds drawn on a U.S. bank or add $20 U.S. to the total amount due. Advance payment and 10 percent per book for postage are required on all orders outside the United States. Wisconsin residents add appropriate sales tax. Send your order to: ASA, CSSA, SSSA Headquarters Office; Attn: Book Order Department; 677 South Segoe Road; Madison, WI 53711-1086 USA. ■

Soil Fertility and Fertilizers– Fifth Edition of Book Now Available

LONG REGARDED as the outstanding book in its field, *Soil Fertility and Fertilizers* is now available in a Fifth Edition. Authors are Dr. Samuel L. Tisdale, Dr. Werner L. Nelson, Dr. James D. Beaton and Dr. John L. Havlin.

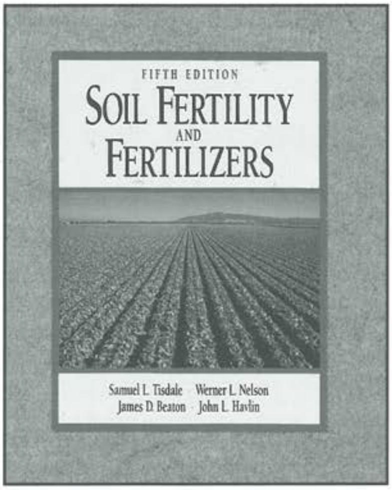
Dr. Tisdale and Dr. Nelson, both now deceased, were authors of the first edition of the text published in 1956. Dr. Beaton and new co-author, Dr. Havlin, have dedicated the Fifth Edition to the memory of Dr. Tisdale and Dr. Nelson.

The text provides a thorough introduction to the biological, chemical and physical properties affecting soil fertility and plant nutrition. The new edition covers all aspects of nutrient management for profitable crop production, with an emphasis on minimizing the environmental impact. It also examines related aspects of soil and crop management for sustained agricultural productivity. The authors have included numerous sample calculations, charts, graphs, photographs, chapter summaries, and worked examples.

Refinements to this edition include a streamlined presentation to make the text more accessible for students. Expanded material relates importance of soil fertility and nutrient management in sustaining long-term agricultural productivity.

Dr. Havlin covers information added to this edition in a style which furthers its effectiveness as a teaching tool. Dr. Havlin, Associate Professor, Soil Fertility, at Kansas State University, is a former winner of the J. Fielding Reed PPI Fellowship award in 1981.

Soil Fertility and Fertilizers, Fifth Edition (ISBN 0-02-420835-3) is available from Macmillan Publishing Company, 445 Hutchinson Avenue, Columbus, OH 43235-5677. Phone (800) 257-5755. Cost of the book is $69.00 plus shipping. ■



Fertilizer Management for Today's Tillage Systems

INCREASING emphasis on conservation tillage and surface residue for erosion control and moisture conservation are placing additional importance on proper fertilizer management for these systems. A publication from agronomists of the Potash & Phosphate Institute (PPI) highlights practices that can improve nutrient use efficiency and increase yields.

The 40-page, 4-color publication is titled *Fertilizer Management for Today's Tillage Systems.* It should be of interest to growers, consultants, fertilizer dealers, Soil Conservation Service personnel, Extension workers, industry representatives, and others.

To order, contact: Circulation Department, PPI, 655 Engineering Drive, Suite 110, Norcross, GA 30092-2821. Phone (404) 447-0335; FAX (404) 448-0439.

The price is $2.00 per copy ($1.00 for PPI member companies, FAR contributors, universities, government, and educational organizations). ■

Environotes from TVA

By John E. Culp

TVA is working with Missouri agencies and industry organizations in a program aimed at "preventing pollution at agrichemical dealerships." The U.S. Environmental Protection Agency (EPA) is also a cooperator in this program. The objective is to prevent potential environmental contamination through changes in design and operation of fertilizer and pesticide handling sites.

The focus of this new program is a demonstration project at Brunswick River Terminal near Brunswick, MO. This is a bulk fertilizer and pesticide dealership. TVA staff are involved in identifying areas where changes in business practices could reduce or prevent pollution of the environment.

We are addressing solid waste, hazardous waste, wastewater, storm water and air quality. The TVA staff are also developing engineering designs, conducting an environmental site assessment, and recommending operational changes to prevent pollution.

This project will help demonstrate ways to successfully reduce or prevent pollution at agricultural dealerships. TVA will conduct educational tours beginning in late 1993 to provide reliable information to agricultural retailers.

Spin-offs will include organizing a pollution prevention information clearinghouse focusing on agriculture and a self-assessment package for fertilizer/agrichemical dealers.

Partners will include the Missouri Department of Natural Resources, Missouri Ag Industries Council, University Extension at the University of Missouri-Columbia, Crowder College, the Environmental Improvement and Energy Resources Authority and the Missouri Department of Agriculture.

TVA Shifts NFERC Emphasis

TVA's National Fertilizer and Environmental Research Center (NFERC) at Muscle Shoals, AL, is restructuring to bolster its work in the environmental area. Dr. Ronald Ritschard, TVA's newly appointed Vice President and Senior Scientist at NFERC, is redirecting the agency's work to demonstrate environmental research and development leadership.

Major focus of the Center's work will be conducting research and developing and introducing new technologies in waste and waste conversions, atmospheric controls, and remediation and cleanup technologies.

Although TVA will shift resources into several areas not currently addressed, the Center will maintain a strong presence in agriculture. It will conduct research to develop cost-effective ways to reduce or prevent nonpoint source pollution from agricultural operations. It will also conduct demonstrations to showcase research results and technology advancements that provide pollution prevention opportunities. Another important objective of the Center will be to encourage the development of a research park around the TVA center.

The recently completed TVA/California video is a tool that agricultural retailers are using in their work with customers. Title of the video is "Grower's Guide to Safe Environmental Handling of Fertilizers." A user's guide is a part of the video package. Both help agricultural retailers provide environmental information to their customers.

For information about this video and eight others developed by TVA, contact the Technical Library, TVA, Post Office Box 1010, Muscle Shoals, Al 35660. ■

John E. Culp is Manager, Technology Introduction, National Fertilizer and Environmental Research Center, Tennessee Valley Authority (NFERC-TVA), Muscle Shoals, AL 35660.

A Great Team

"This afternoon there will be baptisms in both the south and north ends of the church. Babies will be baptized at both ends." (Message from a church bulletin).

There are two sides to every issue. Agriculture is at the crossroads. On one side are those who see hunger as the world's greatest problem. Congressman Tony Hall says, "Twenty-seven million Americans are hungry right now, and 35,000 people around the world will die today." He assigns top priority to food production and distribution.

On the other side are those concerned about the environment and the ecosystem. Congressman Gaylord Nelson, a founder of Earth Day, sees dramatic change in concern about the environment and estimates that 20 million people participate nationwide in environmental causes. He says, "The environment has moved into the establishment."

Can we feed the hungry without depleting our soil resources and devastating the environment? Very fortunately for the world, high production agriculture and *sound* environmental practices go hand in hand and are completely compatible. Our task in agriculture is to communicate these facts to the environmentalists.

The former College of Agriculture at the University of Georgia is now the college of Agricultural and Environmental Sciences. A new option, "Environmental Soil Science", has 27 students enrolled. A few years ago, the option "Soil Science" had dropped to zero!

What marvelous opportunities await us in teaching and research in Agricultural Environmental Science. I only wish I were 20 years old instead of 80. ■

J. Fielding Reed

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