BETTER CROPS
WITH PLANT FOOD

Summer 1992



Featured in this issue: Growth Stages of Wheat

BETTER CROPS With Plant Food

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Circulation Mgr.: Lethia Griffin

Vol. LXXVI (76), No. 3 Summer 1992

BETTER CROPS WITH PLANT FOOD (ISSN: 0006-0089) is published quarterly by Potash & Phosphate Institute (PPI), 655 Engineering Drive, Suite 110, Norcross, GA 30092-2821. Phone (404) 447-0335. Subscriptions: Free on request to qualified individuals; others $8.00 per year or $2.00 per issue.

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Our Cover: Understanding growth stages of wheat can improve the timing of some key management practices. See the article beginning on page 12. Photos by Dr. Travis D. Miller.

Irrigated Spring Wheat Responds to Phosphorus

By John D. Walker, Jim Thorup and Greg Blaser

Idaho studies emphasize the importance of adequate phosphorus (P) for yield, profitability and competitiveness of spring wheat. Adequate P supplies were directly related to wheat's ability to compete with wild oats.

DURING periods of low wheat prices, farmers often dramatically reduce fertilizer inputs. If any fertilizer is used during times of economic stress, it is usually a limited amount of nitrogen (N).

Considerable research has been directed towards the use of P for wheat over the past five years. Researchers have studied rates of application as well as P placement to improve wheat production and maximize returns to growers. As a result of this research, some states are now recommending higher P soil test levels for profitable wheat production.

Data summarized and released by the Tennessee Valley Authority show that there is a substantial need for improved P fertilization of wheat. Kansas farmers applied an average of 13 lb/A of P_2O_5 for wheat in 1990. Farmers in Colorado and Washington applied an average of only 4 and 6 lb/A P_2O_5, respectively.

Considering the fact that wheat removes approximately 0.5 lb of P_2O_5 per bushel of production, many farmers are still "mining" their soils of P. Kansas farmers applied enough P for only 26 bushels of wheat, while those in Colorado and Washington applied enough for only 8 and 12 bu/A, respectively. Since state average production figures are considerably higher than these numbers, available P continues to decline. Research shows that yields suffer in many areas as a result of this neglect.

Plots were established in 1989 at the Ricks College Hillview Farm to study N and P rate effects on yield of irrigated hard

PHOSPHORUS is frequently a limiting nutrient for both dryland and irrigated wheat in Idaho and surrounding areas. This photo shows the effects of added P (left) versus no P (right) with the same amount of available N. Yield, water use efficiency, N use efficiency and overall profitability improve with adequate P.

Dr. Walker is Chairman, Agronomy Dept., Ricks College, Rexburg, ID; Dr. Thorup is Agronomist, Chevron Chemical Company, Fertilizer Division (now retired); Greg Blaser is Associate Professor, Agronomy Dept., Ricks College, Rexburg, ID.

Table 1. Irrigated spring wheat response to P–1989.

Treatment, lb/A		Yield,	Protein,	Net return to land and capital, $/A	
N	P_2O_5	bu/A	%	$4.00/bu	$3.50/bu
120	0	64	13.2	39	7
120	50	77	13.3	79	53
120	100	76	13.4	63	25
180	0	71	14.0	54	18
180	50	85	13.6	98	56
180	100	82	14.5	74	33

Nitrogen, $.22/lb; P_2O_5, $.24/lb. Variable costs except fertilizer $190/A.

red spring wheat. The initial soil test level for sodium bicarbonate extractable P was 15 parts per million (ppm). Many consider this soil P level to be more than adequate for wheat production.

Four rates of N (0, 60, 120, 180 lb/A) and three rates of P (0, 50 100 lb/A P_2O_5) were utilized. Nitrogen was applied as ammonium nitrate broadcast just prior to planting. Phosphorus (monoammonium phosphate) was applied with the seed using a Concord Air Seeder.

Large plots (34 x 100 ft.) were used so field-scale equipment could be accommodated for planting and harvesting. The area has been under no-till management for the past 15 years.

Results

In the first year of the study, P increased yields at all rates of N by as much as 25 bu/A. Highest returns resulted from the application of 180 lb/A N and 50 lb/A P_2O_5 (**Table 1**).

Second year data (1990) showed similar increases from N and P, but yields were reduced substantially due to excessive heat and wind and the inability to move hand lines fast enough to prevent damage to the crop.

In the third year under center pivot irrigation, P was applied to half of each plot to assess residual effects. Continued P application increased yields up to 26 bu/A (**Table 2**). Residual P produced smaller yield increases . . . a maximum of 16 bu/A from 100 lb/A P_2O_5 and 180 lb/A N. This combination also produced highest net profits. The 100 lb/A P_2O_5 residual effects resulted in yield increases at every rate of N. This was not true with the 50 lb/A P_2O_5 residual plots.

Soil Test P

Soil samples were collected in October 1991 to determine changes in soil available P levels (**Table 3**). Soil test values were close to calculated numbers using a value of 9 lb P_2O_5 to increase soil test P by 1 lb/A. Using the 180 lb N and 100 lb/A P_2O_5 treatment as an example, 300 lb/A P_2O_5 was applied during the 3-year study.

Table 2. Spring wheat reponse to annual and residual P applications–1991.

Treatment, lb/A		Yield,	Protein,	Net return to land and capital, $/A	
N	P_2O_5	bu/A	%	$4.00/bu	$3.50/bu
120	0	63	12.4	35	3
120	50	77	12.9	79	41
120	Residual	61	12.5	27	-4
120	100	78	12.8	71	32
120	Residual	67	12.7	51	17
180	0	75	12.8	69	31
180	50	92	13.4	125	79
180	Residual	87	13.1	117	73
180	100	101	13.3	149	99
180	Residual	91	13.2	133	87

Residual received indicated rate of P_2O_5 for 2 years. Nitrogen $.22/lb; P_2O_5 $.24/lb. Variable costs except fertilizer $190/A.

ADEQUATE P helps wheat compete with weeds. Wild oats have dominated (right) where P was not provided, even though both plot areas received herbicide. The plot on the left received 100 lb P_2O_5/A.

Table 3. Effects of P fertilization of sodium bicarbonate extractable soil P.

Treatment	Sodium Bicarbonate Extractable P, ppm
Initial sample (September, 1989)	15
180 N, 50 P_2O_5	20
180 N, 100 P_2O_5	25

Sampled October 1991.

Approximately 250 bu/A of wheat was harvested during that period, containing approximately 0.5 lb P_2O_5 per bushel (125 lb P_2O_5/A) and leaving a net of 175 lb/A P_2O_5 in the soil. Dividing 175 lb P_2O_5 by 9 gives a possible soil test increase of about 19 lb/A or 9.5 ppm. The measured value of soil test change during the period was 10 ppm (**Table 3**), an increase from 15 to 25 ppm.

Based on recent studies in the northern Great Plains and Prairie Provinces, some researchers are now recommending a critical level of 22 to 25 ppm sodium bicarbonate extractable P for optimum wheat production. Growers whose soils test below that range are encouraged to use or evaluate P use in their production systems for higher yields, higher profits, better water use efficiency and soil protection. Large-scale (1,300 acres) implementation of the results of this study on hard red spring irrigated wheat produced an average yield of 105 bu/A, an increase of 14 bu/A over a 40-acre control area which had an initial sodium bicarbonate extractable P test of 15 ppm.

Weed Pressure

In addition to yield increases, observations of weed pressure in the study indicated an advantage in plots receiving adequate N and P. Herbicides were applied for the control of wild oats and other weeds. However, in the residual P study area in 1991, wild oat pressure developed as the crop neared harvest. Pressure was much greater in plots without adequate P. Apparently, wild oats could not compete with vigorously growing wheat which received adequate P.

Summary

Data from this 3-year study show the importance of an adequate fertilization program on yields and profits from hard red spring wheat in eastern Idaho. Use of adequate P for wheat on soils testing medium or below in available P will result in increased rate of growth, lowered competition from weeds, higher N use efficiency, improved water use efficiency, higher yields, and higher profitability. ■

Ohio Research

Nitrate in Private Rural Water Supplies: Building Local Data Bases

By David B. Baker

Information on nitrate (NO_3) contamination in local areas can support the development of locally appropriate responses to concerns regarding agricultural contamination of groundwater. Often, local data are unavailable. Since NO_3 contamination is so variable, national, statewide and even county average data may be of little use in optimally addressing local groundwater issues. Cooperative well testing programs provide a rapid, efficient and low cost means to develop local data bases.

IS CONTAMINATION of private drinking water supplies with NO_3 a problem in your county, in your neighborhood, or your own well? Can you respond to these concerns as they relate to nitrogen (N) fertilizer rates, sources of N, and N use efficiency? Can you support your answers with relevant data? The answers may have a significant impact on the future choices you will have in N fertilizer management.

To help agricultural organizations develop local data bases on the extent of NO_3 and pesticide contamination, our laboratory, in cooperation with the American Farm Bureau Federation, has developed the Cooperative Private Well Testing Program. In this program, local organizations, such as soil and water conservation districts or Farm Bureau groups, sponsor a county-wide well testing program. Individual residents, who volunteer to participate, pay a relatively low fee to have their wells tested and receive a confidential report on their well. The sponsoring organizations receive summaries and maps of the results from all wells tested in their county.

Since 1987, 34,000 rural residents from 276 counties and 15 states have submitted water samples to our laboratory for testing as part of this program. The kinds of data generated are illustrated in this report. All NO_3 concentrations are reported as NO_3-N.

Overall Results

The distribution of NO_3-N concentrations in the entire data set is shown in **Figure 1**. Nitrate concentrations in excess of the safe drinking water standard were present in 3.8 percent of the wells tested. The standard is 10 milligrams per liter (mg/L) or 10 parts per million (ppm). In another 11.9 percent, NO_3-N concentrations fell between 3.0 and 10 ppm. Together, these two groups represent the fraction of wells in which NO_3-N concentrations are likely to be reflecting the effects of various human activities. In 21.3 percent of the wells tested, NO_3-N concentrations fell between 0.3 and 3.0 ppm, while in the remaining 63 percent, concentrations were less than 0.3 ppm. On a nationwide basis, the U.S. Environmental Protection Agency (EPA) has estimated that NO_3-N exceeds the safe drinking water standard in about 2.4 percent of the approximately 10.5 million rural domestic wells.

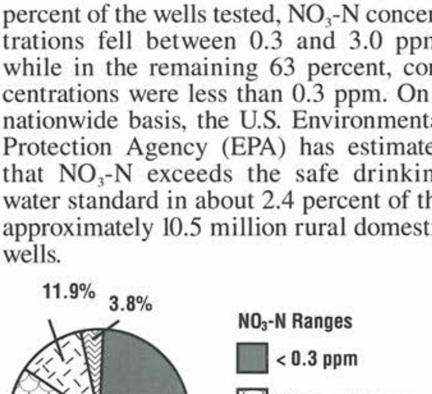


Figure 1. Distribution of NO_3-N concentrations in 33,753 private water supplies.

Dr. Baker is Director of the Water Quality Laboratory at Heidelberg College, Tiffin, OH 44883.

State-to-State Variability

Extensive testing of private water supplies by state agencies is largely confined to those states with greater vulnerability to NO_3-N contamination, such as Iowa and Nebraska. Recent studies in Iowa suggest that NO_3-N exceeds 10 ppm in about 18 percent of that state's private wells. In Nebraska, about 20 percent of the well samples tested for NO_3-N exceed 10 ppm, although Nebraska data don't necessarily reflect statewide conditions.

As part of our program, extensive private well testing has been extended to states which are less vulnerable to NO_3-N contamination. In **Table 1**, the extent of NO_3-N contamination in the eight states with the largest participation is summarized. For most of these states, only a small proportion of the counties has been tested, and consequently, the NO_3-N concentration data are not necessarily representative of the entire state. In Ohio, Indiana and Kentucky, the three states with the largest data sets, the portion of wells exceeding 10 ppm NO_3-N was only 3.0 percent, 3.5 percent and 4.6 percent, respectively.

County-to-County Variability

One of the more striking features of the data set is the extensive variability among counties with regard to NO_3-N concentrations. **Figure 2** illustrates the variability for the 201 counties for which there were 25 or more wells tested. In 71 counties, the average concentrations were between 0 and 1.0 ppm. County average concentrations exceeded 3.0 ppm in 28 counties.

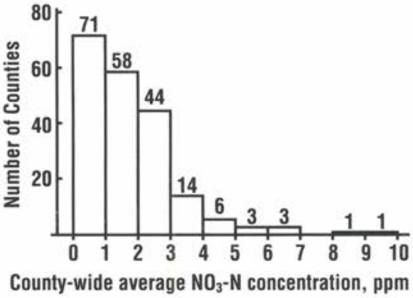


Figure 2. Distribution of county average NO_3-N concentrations.

Figure 3 illustrates the variability among these same counties in the percentage of wells exceeding the safe drinking water standard. In 88 counties, NO_3-N exceeded 10 ppm in less than 2 percent of the wells. In 23 counties, more than 8 percent of the wells tested exceeded 10 ppm. These graphs indicate that, for the large majority of counties, NO_3-N contamination is uncommon.

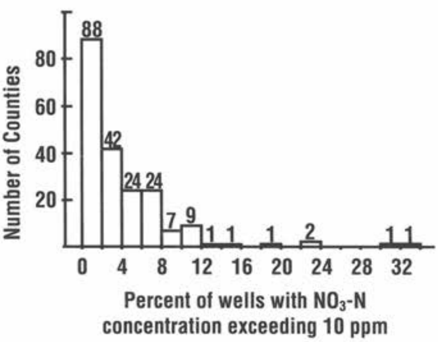


Figure 3. Distribution of the percentage of wells exceeding the drinking water standard.

Table 1. Summary of NO_3-N data for states with largest participation in the Cooperative Private Well Testing Program.

State	Counties tested	Number of samples	Average concentration NO_3-N, ppm	Percent over 10 ppm NO_3-N
Illinois	8	286	5.76	19.9%
Indiana	33	5,685	0.92	3.5%
Kentucky	90	4,559	2.50	4.6%
Louisiana	23	997	1.19	0.8%
New Jersey	5	1,108	2.60	6.8%
Ohio	80	18,202	1.32	3.0%
Virginia	24	1,054	2.92	7.1%
West Virginia	13	1,288	0.83	0.8%
Totals	276	33,179	1.54	3.5%

Many of the counties with low levels of NO_3-N contamination are counties in which row crop agriculture is the dominant land use. In Ohio, there is no correlation between county N fertilizer sales and county average NO_3-N concentrations (**Figure 4**). For these same Ohio counties, there is a correlation between vulnerability to contamination, as estimated by a groundwater vulnerability model, and NO_3-N contamination in wells (**Figure 5**).

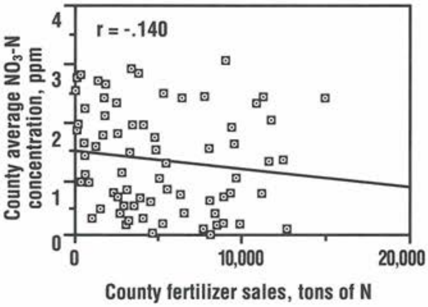


Figure 4. Relationship of county N fertilizer sales and county average NO_3-N concentrations.

Within County Variability

Often NO_3-N contamination is much more prevalent in some areas of a county than in other areas. Our testing program provides maps which illustrate the patterns of NO_3-N concentration in individual counties. Those familiar with the soils, geology and land use in a particular county can often provide logical explanations for the NO_3-N contamination patterns evident in the county maps.

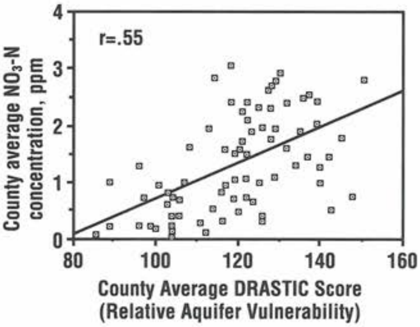


Figure 5. Relationship between county average NO_3-N concentration and county average vulnerability.

Individual Well Characteristics

Several characteristics of well construction also influence the likelihood of NO_3-N contamination in private wells. Along with the water sample, each participant in this program submits a sheet containing information about well construction. Comparisons of NO_3-N concentrations with data from the information sheets illustrate these relationships (**Table 2**). As a whole, springs, dug wells and driven wells (e.g., sand point wells) have much greater levels of contamination than drilled wells. **Shallow wells and older wells are more likely to be contaminated than deeper wells and newer wells.**

Table 2. Summary of well characteristics in relationship to NO_3-N concentration.

Well characteristic	Number of samples	Average concentration NO_3-N, ppm	Percent over 10 ppm NO_3-N
Year Drilled Summary			
1800s	244	4.01	13.1%
1900-1949	2,940	2.03	5.6%
1950-1970	7,475	1.32	2.9%
after 1970	10,377	1.12	2.3%
Well Depth Summary			
< 50 ft.	5,042	2.45	8.5%
50-100 ft.	10,167	1.42	3.5%
over 100 ft.	8,250	0.94	1.6%
Construction Type			
Drilled	12,750	1.43	3.5%
Driven	1,263	2.84	8.8%
Dug	1,080	4.75	12.5%
Springs	1,550	2.91	5.7%

Temporal Variability

Surveys of the type conducted in this program provide a "snapshot" in time of the NO_3-N concentrations in water rural residents are consuming. How constant are the concentrations in private rural wells? In Ohio, we have conducted follow-up studies in which we have monitored individual wells on a weekly or biweekly basis for a year. When we selected wells simply on the basis of existing levels of contamination (i.e., we wanted to be sure the wells initially contained NO_3-N), we found that there was a large month-to-month variability in individual wells, and that the amount of variability increased with increasing initial concentration. Nitrate concentrations in many wells were below the drinking water standard some of the time, but above the standard at other times. Seasonal effects were not evident. When we selected wells based on information regarding (1) the specific aquifer tapped by the well, (2) indications of proper well construction and (3) the occurrence of NO_3-N contamination, the choices of wells for study became quite restricted and the extent of variability observed was much less.

These results suggest that, at least for Ohio, most contaminated wells are either tapping shallow aquifers that respond rather quickly to variations in weather conditions or are improperly constructed or maintained, such that contaminated surface water periodically enters the well.

Trends in Nitrate Concentrations

While many wells in agricultural areas currently show essentially no evidence of NO_3-N contamination, it would be very useful to know whether or not a continuation of current agricultural N management practices in these same areas would eventually lead to increasing levels of NO_3-N contamination. Information regarding current and future trends in NO_3-N contamination is very difficult to obtain. This question can be approached either through research on the fate of N within the soil and unsaturated zone along groundwater recharge pathways or by the establishment of appropriate trend monitoring programs. Programs to address the issue of long-term trends in NO_3-N contamination are being initiated in several areas. It is likely that the answers to this question will also be site specific.

Conclusions

Information on NO_3-N contamination in rural private wells underscores the following:

- The extent of NO_3-N contamination in rural wells varies greatly from region to region.
- In most areas, NO_3-N contamination is uncommon.
- Minimal NO_3-N contamination is present in many areas of intensive row crop agriculture, while areas of more extensive contamination occur both in agricultural and nonagricultural regions.
- Shallower and older wells are more likely to be contaminated than deeper and newer wells; and springs, driven wells and dug wells are more likely to be contaminated than drilled wells.
- Where contamination is present, NO_3-N concentrations often exhibit considerable month to month variability, especially when the wells are tapping shallow aquifers and/or suffer from faulty construction.
- The question of appropriate N management in a given area depends not only on the current extent of NO_3-N contamination in that area, but also on local trends in contamination.

Cooperative private well testing programs offer a means to rapidly develop a local data base on the extent of NO_3-N contamination in private rural wells in a given area. The resulting information can be used to help assure that agricultural programs addressing groundwater concerns are appropriate for the local conditions. Rural well contamination is generally a local problem requiring local solutions, and local solutions often benefit from local data. ■

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

FOUR outstanding graduate students have been announced as 1992 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 1992 recipients were chosen from nearly 40 applicants who sought the Fellowships. The four are:

- **Matthew L. Adams, Cornell University**, Ithaca, New York;
- **Matthew G. Hanson, University of Arkansas**, Fayetteville;
- **T. Scott Murrell, Texas A&M University**, College Station;
- **William Bart Stevens, Brigham Young University**, Provo, Utah;

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. "These individuals 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:

Matthew L. Adams, born in Fresno, CA, was awarded a B.S. degree in Agricultural Science, summa cum laude, at California State University, Fresno, in May of 1990. He is currently completing his M.S. degree at Cornell University and plans to continue studies toward the Ph.D. His master's research deals with the use of remote sensing techniques to detect manganese (Mn) stress in soybeans (*Glycine max* cv 'Bragg'). Soybeans were grown under controlled conditions in chelate-buffered hydroponic solutions to regulate the supply of Mn. Reflectance and fluorescence emission spectra, as well as specific characteristics of induced fluorescence of leaves, were evaluated to identify Mn stress. Later experiments will identify nutritional and spectral changes associated with copper (Cu), iron (Fe), and zinc (Zn) stress. Following graduate school, Mr. Adams hopes to work in a research position.

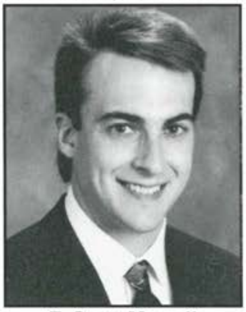

Matthew L. Adams

Matthew G. Hanson is working toward his M.S. degree at the University of Arkansas. Born in Hudson, WI, he received his B.S. degree in agriculture from the University of Wisconsin-River Falls in June of 1990, graduating with honors. His M.S. thesis title is "Identification of Soils with Chemical Properties that May Inhibit Deep Root Growth." Working with 16 soils representing more than a million


Matthew G. Hanson

acres of croplands in eastern Arkansas, he has run analyses to depths as great as three feet to determine levels of elements that are essential or detrimental to plant growth. Nearly all the soils were found to be deficient in phosphorus (P) and potassium (K), even in the top foot of soil. Several soils were found to have very acid pHs and high levels of exchangeable aluminum (Al) in the upper foot. An inverse relationship was found between root length and Al concentrations. After completing his M.S. degree, Mr. Hanson plans to work for a private firm in Wisconsin. His long-term goal is to obtain a Ph.D. degree in soil fertility and teach or work in Extension.

T. Scott Murrell was born in Winchester, IN. He earned a B.A. degree, with distinction, in general history at Purdue University in 1986. He did graduate work at Yale University before returning to Purdue, where he was awarded the M.S. degree in agronomy in December, 1991. He is currently pursuing a Ph.D. degree in soil chemistry at Texas A&M University. His dissertation title is "Gradient Diffusion of Nutrients for Crop Production." His research will focus on the incorporation of a concentration gradient into an ion diffusion model, to more accurately reflect natural systems. Estimated nutrient uptake calculated from his model will then be compared to that predicted by models where concentration has been assumed to be constant. Crop uptake observed in the field and greenhouse will be compared to model estimates, along with an evaluation of the model's ability to predict nutrient requirements in best management practice (BMP) crop production. Mr. Murrell's career goal is to conduct research that will bridge the gap between basic and applied research.



T. Scott Murrell

William Bart Stevens is a native of Cowley, WY. He attended Ricks College in Rexburg, ID, earning an Associate Degree in crop and soil science in 1988. He entered Brigham Young University (BYU) in the fall of 1988 and was awarded his B.S. degree, summa cum laude, in crop science in the spring of 1991. He is currently studying for his M.S. degree in agronomy at BYU. Mr. Stevens' research is focused on the screening of soybean cultivars grown in nutrient solution to identify those which can utilize oxidized soil iron (Fe^{+3}), the insoluble, plant-unavailable form common to high pH soils. The basis of his screening method is to quantify cultivar ability to reduce Fe^{+3} to Fe^{+2} at the root plasma membrane. If successful, Mr. Stevens' research will result in more rapid, less expensive screening procedures for establishing Fe-efficient crops. He plans to continue his studies through the Ph.D. level.

William Bart Stevens

The Fellowship winners are selected by a committee of individuals from PPI staff and the PPI Advisory Council. The Fellowships are named in honor of Dr. J. Fielding Reed, retired President of the Institute, who now lives in Athens, Georgia.

Dr. W.R. Thompson, Jr., PPI Midsouth Director, served as chairman of the selection committee for the 1992 Fellowships. "The knowledge, dedication and high ideals of the 1992 applicants were quite evident. It is reassuring to note the achievement and goals of these young people, not only in academic work, but also in other aspects of their lives," he stated. ■

Growth Stages of Wheat: Identification and Understanding Improve Crop Management

By Travis D. Miller

Understanding growth stages of wheat is important in matching management decisions and inputs with plant development. This article outlines characteristics and management decisions that may be associated with indicated stages of plant growth.

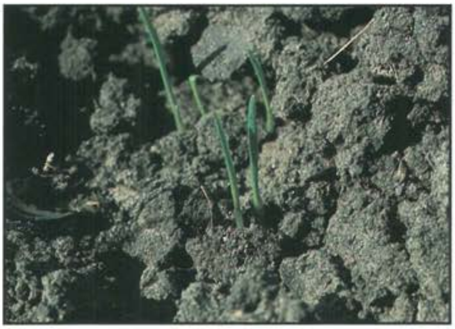
THERE ARE at least five scales commonly used worldwide to describe stages of growth of wheat and other small grains. The scale used is not important, as long as the grower has a thorough understanding of the growth habit of wheat and how management inputs at specific growth stages can affect forage and grain yield.

Probably the most widely used scale in the U.S. is the Feekes scale, although the Zadoks and Haun scales are more detailed and descriptive. Careful study of the developing crop and an intimate knowledge of factors which may have positive or negative effects on forage and grain yield potential can enhance management decisions. These decisions can make wheat production more profitable.

This article discusses management of the wheat crop in terms of the Feekes growth scale and provides visuals of those growth stages.

Feekes 1.0–Emergence, one shoot formed.

If desired, number of leaves present on the first shoot can be designated with a decimal. For example, 1.3 is a single shoot with three leaves unfolded. Without a doubt, the most significant event in achieving high yield of grain and/or forage in wheat is stand establishment. Planting high quality seed of an adapted wheat variety in a fertile, well prepared seedbed with enough moisture to achieve a rapid, uniform stand is a significant step in achieving acceptable yields.



Seedling emergence–Feekes 1.0

Late planted wheat has less time to tiller and should be planted at a higher rate to compensate for fewer tillers. If early forage production is a goal, producers should increase seeding rates and depend less on tiller formation to produce early forage growth.

Dr. Miller is Professor and Extension Agronomist–Small Grains and Soybeans, Dept. of Soil and Crop Sciences, Texas A & M University, College Station, TX 77843.

Beginning of tillering–Feekes 2.0

Tillers formed–Feekes 3.0

Feekes 2.0–Beginning of tillering.

A tiller is a shoot which originates in the axil of a leaf or at the coleoptilar node. Tillers share the same root mass with the original shoot or main stem. Once established, secondary tillers may arise from the axils of the primary tillers; tertiary tillers may develop from the axils of secondary tillers, etc.

During tillering, the major management consideration is whether stands are adequate to achieve yield goals. Management inputs will not compensate for skippy or erratic stands caused by insects, poor seed quality, herbicide injury, etc. If stands are thin, but uniform, an early nitrogen (N) application may enhance the rate of tillering, potentially increasing the number of heads per square foot. Care must be taken with fall N application. If heat units are available, excess N applied at this time leads to a lush, vegetative growth which makes the crop more susceptible to winterkill, foliar fungal disease, and aphid injury. Adequate phosphorus (P) is strongly related to rooting and tiller development. If tiller development is a historic problem in a given field, close attention must be given to P soil test recommendations prior to planting.

Feekes 3.0–Tillers formed.

Winter wheat can continue to tiller for several weeks. Depending upon planting date and weather conditions, tillering can either be interrupted by or completed prior to the onset of winter dormancy. Most of the tillers that contribute to grain yield potential are completed during this stage. Leaves begin to twist spirally. Many winter wheats are prostrate or "creeping" at stage 3.

Major yield potential loss can occur from weed infestation during tiller formation, as weeds compete for light, water and nutrients. Once the wheat has achieved full canopy, little problem is experienced from weeds. Weed control decisions should be made before or during Feekes 3.0. The herbicide metribuzin may be applied for postemergence grass and broadleaf weed control during this growth stage on tolerant wheat varieties. In most cases, plants should have at least 4 tillers and be actively growing before application of this herbicide. The herbicide 2,4-D and similar phenoxy herbicides should not be applied until wheat is fully tillered, or after Feekes 3.0.

Growers should carefully scout for aphid and other insect infestations during Feekes 2.0 and 3.0, as stress from insect injury can reduce tiller formation. Control thresholds are much lower on small plants than later when plants are larger.

Feekes 4.0–Beginning of erect growth, leaf sheaths lengthen.

Most tillers have been formed by this stage, and the secondary root system is developing. Winter wheats which may have a prostrate growth habit during the

(continued on next page)

Beginning of erect growth–Feekes 4.0

Leaf sheaths strongly erect–Feekes 5.0

development of vegetative parts begin to grow erect. Leaf sheaths thicken. The key management step at Feekes 4.0 is continued scouting for insect and weed infestations. Some growers initiate grazing during Feekes 4.0.

Feekes 5.0–Leaf sheaths strongly erect.

At this stage, the wheat plant becomes strongly erect. All meaningful tiller development has ceased. Many varieties of winter wheat which are creeping or low-growing during tillering, grow vertically at this stage. The vertical growth habit is caused by a pseudo or false stem formed from sheaths of leaves. In early planted wheat in southern areas of the U.S., this stage can occur prior to the onset of winter dormancy.

Further development of the winter wheat plant requires vernalization, or a period of cool weather. After the appropriate amount of chilling, followed by the resumption of growth, the growing point (which is located below the soil level at the crown) differentiates. This means that all leaves have been formed and the growing point, which generates new cells for the plant, will begin to develop an embryonic head. At this stage of growth, the size of heads, or number of spikelets per spike, is determined. No effect on yield is expected from tillers developed after Feekes 5.0. Nitrogen applied at Feekes 5.0 can affect number of seed per head and seed size, but will not likely affect number of heads harvested. This is an ideal stage of growth for the spring topdress N application as later applications will not affect the potential number of seed per head.

Irrigation management can be critical during the spikelet differentiation process. Extreme stress during this differentiation process can reduce potential number of seeds per head, which is an important component of yield. Wheat stressed during the head differentiation process at Feekes 5.0 will have blank portions of the head, frequently on the ends.

Take great care with grazing operations, particularly on short wheats, during this growth stage. Final plant size, leaf area, and yield are closely related to the severity of grazing. This is true of wheat harvested for grain and wheat intended for graze-out. Tall wheats are more tolerant of severe grazing at this stage of growth. Rotate cattle with a goal of leaving a minimum 3 to 4 inches of green leaf area going into Feekes 6.0.

Feekes 6.0–First node visible.

This stage of growth is easy to identify. Feekes 6.0 will not occur prior to the onset of cold weather, as vernalization is required in winter wheats prior to spikelet differentiation. Prior to Feekes 6.0, the nodes are all formed, but are sandwiched together so that they are not readily distinguishable to the naked eye. At 6.0 the first node is swollen and appears above the soil surface. Above this node is the head, or spike, which is being pushed upwards to eventually be exerted from the boot. The true stem is now forming. The spike at this stage is fully differentiated, containing all potential spikelets and florets or seed forming branches.

Growers should look carefully for the first node to emerge. It can usually be seen and felt. A sharp knife or razor blade is useful to split stems to determine the location of the developing head. The stem is hollow in most wheat varieties behind this node. By Feekes 6.0, essentially all weed control applications have been made. Do not apply phenoxy herbicides such as 2,4-D, Banvel or MCPA after Feekes 6.0, as these materials can be translocated into the developing spike, causing sterility or distortion. Sulfonyl urea herbicides are safe at this growth stage, but for practical reasons, weed control should have been completed by now.

All grazing should cease by Feekes 6.0. Mechanical injury by livestock to the spikes at this time means direct loss of grain yield. But a more significant effect on potential yield comes from loss of leaf area to grazing at this stage.

Small grains can still show good response to N topdressed at this time, although yield responses will be better at Feekes 5.0 as head size can no longer be affected by fertilizer application. Mechanical injury to wheat can occur from fertilizer applicators at this stage of growth, but response to applied N will usually more than compensate for the damage if soil N is deficient.

Feekes 7.0–Second node visible, next to last leaf visible.

This stage is characterized by the rapid expansion of the spike and the appearance of a second node above the soil surface.

First node visible–Feekes 6.0

Second node visible–Feekes 7.0

(continued on next page)

Feekes 8.0–Flag leaf visible.

This growth stage begins when the last leaf (flag leaf) beings to emerge from the whorl. This stage is particularly significant because the flag leaf makes up approximately 75 percent of the effective leaf area that contributes to grain fill. When the flag leaf emerges, at least 3 nodes are visible above the soil surface; occasionally a fourth node can be found. To confirm that the leaf emerging is the flag leaf, split the leaf sheath above the highest node. If the head and no additional leaves are found inside, stage 8.0 is confirmed.

At Feekes 8.0, the grower should decide whether to use foliar fungicides or not. This decision should be based upon the following considerations:

1. Is a fungal disease present in the crop?
2. Does the crop have resistance to the fungal disease, or is the disease spreading rapidly?
3. Does the crop yield potential warrant the cost of application of the fungicide in question to protect it?
4. Is the crop under stress?

Flag leaf visible–Feekes 8.0

If a positive answer applies to the first three questions, and a negative response to the last, plans should be made to protect the crop, especially the emerging flag leaf, from further damage. Check product labels and apply as soon as possible. In most situations, the greatest return to applied foliar fungicides comes from application at Feekes stage 8.0 to 9.0. There is a considerable debate about pre-emptive applications of fungicides to prevent future infestations of fungal diseases. In certain high disease and high yield environments, this may be justified.

Nitrogen applications at Feekes 8.0 and later can enhance grain protein levels, but are questionable with respect to added yield.

Irrigation scheduling becomes most critical between Feekes 8.0 and mid-grain (Feekes 11.1). The crop should not be stressed from about 10 days prior to bloom through the late milk stage. Feekes 8.0 marks a point in the development of the wheat plant beyond which every effort should be made to apply water to prevent loss in grain yield potential.

Feekes 9.0–Ligule of flag leaf visible.

Stage 9.0 begins when the flag leaf is fully emerged from the whorl. From this point on, leaves are referred to in relation to the flag leaf, i.e.; the first leaf below the flag leaf is F-1, the second leaf below is F-2, etc. The wheat plant typically produces 7 to 9 true leaves, not inclusive of leaves on the tillers. After flag leaf emergence, army worms can seriously damage yield potential.

Ligule of flag leaf visible–Feekes 9.0

Feekes 10.0–Boot stage.

The head is fully developed and can be easily seen in the swollen section of the leaf sheath below the flag leaf. The Feekes growth scale at stage 10 is divided as follows:

Feekes	10.0	boot stage
	10.1	awns visible, heads emerging through slit of flag leaf sheath
	10.2	heading ¼ complete
	10.3	heading ½ complete
	10.4	heading ¾ complete
	10.5	heading complete
	10.5.1	beginning flowering
	10.5.2	flowering complete to top of spike
	10.5.3	flowering complete to base of spike
	10.5.4	kernels watery ripe

Wheat is largely self pollinating. Most florets are pollinated before anthers are extruded. Although tillers have developed over a several week period, bloom in a given wheat plant is usually complete in a few days. After Feekes stage 10.5.3, remaining growth stages refer to ripeness or maturity of the kernel.


Boot stage–Feekes 10.1


Beginning flowering–Feekes 10.5.1

Feekes 11.0–Ripening

Feekes	11.1	milky ripe
	11.2	mealy ripe
	11.3	kernel hard
	11.4	harvest ready

Bloom occurs 4 to 5 days after heading. The grain fill period of wheat varies somewhat, depending upon climate. It is typically as little as 30 days in high stress environments, and may exceed 50 days in high yield, low stress environments. ■


Wheat mature and harvest-ready–Feekes 11.4

Missouri Research

Phosphorus and Potassium Affect Alfalfa Persistence

By Jerry Nelson, Daryl Buchholz, Kevin Moore, and John Jennings

Missouri research demonstrates that phosphorus (P) and potassium (K) fertilization are keys to both alfalfa yields and stand persistence. Adequate K has a strong effect on increased stem numbers per plant, a major factor in yield improvement in thin stands.

ALFALFA, the queen of forages, is recognized widely for its high yield potential and excellent forage quality. Only a few management studies, however, have included plant persistence evaluations over a long period of time. Recently, there has been an increased interest in persistence of alfalfa, arising largely due to:

- the high cost of establishment;
- the need to prevent erosion during establishment on marginally-productive soils;
- the interest in high quality forage for low-cost feeding systems;
- the growing recognition that alfalfa is cost-effective for growing beef animals as well as dairy production.

Invariably, with this shift in adaptation to more marginal sites, there is a need to focus more managerial attention toward persistence. The life of the stand becomes a very important economic factor.

The Stand

A major objective in alfalfa management is to rapidly establish a high number of plants that can be maintained over a long period of time. Alfalfa (with 90 percent germination seeded at 15 lb/A) has a potential of 70 seedlings per square foot. At the end of the seeding year, however, 20 to 25 plants per square foot is considered an excellent stand. Thereafter, the stand will decrease in plant density, rapidly at first as self-thinning occurs, until about 6 plants per square foot remain (generally about 3 years later). Depending on management, the stand then depletes slowly, until the plant density no longer supports economic yields (**Figure 1**).

Missouri Research

Research on plant persistence began because farmers needed management

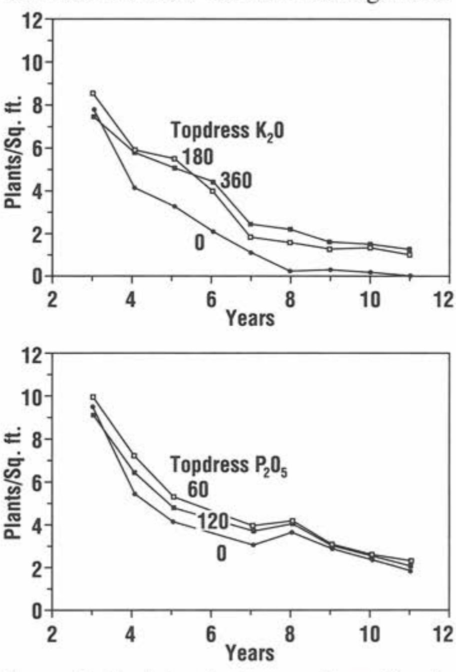


Figure 1. Plant density decreased over time in experiments without adequate P or K. Plots were topdressed annually with K (top) or P (bottom), the other nutrient being kept at a high level. Note the rapid decrease in plant density, and how failure to topdress with K led to continued rapid plant loss.

The authors are with the University of Missouri, Columbia. Dr. Nelson is Curators' Professor and Dr. Buchholz is State Extension Soils Specialist, Department of Agronomy; Dr. Moore is State Extension Farm Management Specialist, Department of Agricultural Economics; John Jennings is Area Agronomist (West Plains).

information. Many in Missouri were experiencing problems with longevity of alfalfa on certain soil types (especially those with poor fertility or drainage). The objectives of this research were focused mainly on marginal soil sites and involved conservative management variables to maintain production and improve persistence. Alfalfa yields and the effects on plant stem growth were monitored over time as plant densities decreased. These findings were based on six separate experiments, some lasting more than 10 years.

Two fertility trials in Howell county, MO, conducted for the past 10 years, have demonstrated that fertilizer management is a critical aspect of a productive alfalfa system. **Figure 2** shows the direct effect of fertility on yield, but persistence also has great economic implications for farmers. Sound fertility management allows the farmer to extend the useful life of the stand (possibly 2 to 4 more years) and decrease amortized establishment costs. Clearly, a good economic strategy for longer crop persistence is fertilizer management.

Research Results

Plowdown treatments of K on a soil with 92 parts per million (ppm) extractable K had only a small influence on yield and plant persistence (limited to the first 2 years). For example, averaged over topdressing treatments, plots receiving no plowdown K yielded about 85 percent as much as plots receiving 200 or 400 lb/A plowdown K_2O, which were equal (data not shown). The 100 lb/A K_2O plowdown treatment was intermediate. There was no influence on plant density. In contrast, topdressing treatments of K had a marked effect on both plant persistence (**Figure 1**) and yield (**Figures 2 and 3**).

At a second site with a low Bray P-1 level of 4.5 ppm, there was a slight yield response for the first 2 years due to plowdown treatment of P (data not shown), but the major long-term effects came from topdressed P (**Figure 3**). These data emphasize the importance of annual topdressing of P and K.

Annual topdressing (especially in the later years), averaged over plowdown treatments, had a marked effect on yield and plant density. Stand density declined more rapidly without topdressed K (**Figure 1**) reaching the critical value of three plants per square foot after the 5th year (1985). After 10 years (1990), plots receiving 180 or 360 lb K_2O/A had been reduced to fewer than two plants per square foot, and yield was decreasing (**Figure 2**).

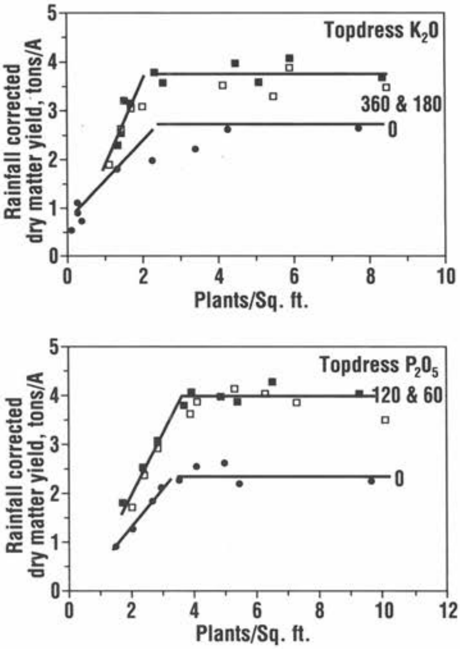


Figure 2. Yields corrected for year-to-year variation in rainfall, then plotted relative to plant density. The "trend" is for a minimal density of about 2 to 3 plants per square foot for maintaining high yield. Topdressed P or K treatments were averaged because they responded similarly. Note that yield tended to be independent of plant density at high densities, but topdressing increased yield at a given density.

Weed control was a critical aspect of extended yield and stand life. Winter annuals were treated with paraquat when plant density was below four plants per square foot. Both winter and summer annuals were treated when density was below three plants per square foot. When costs of annual weed and insect control were included, the topdressed stands were still economic after 8 years (when yield began to decline).

POTASSIUM is important in maintaining alfalfa plant stands as well as yields. Photos above show plots which received 360 lb/A K_2O rates (left) compared to plots receiving no K_2O (right).

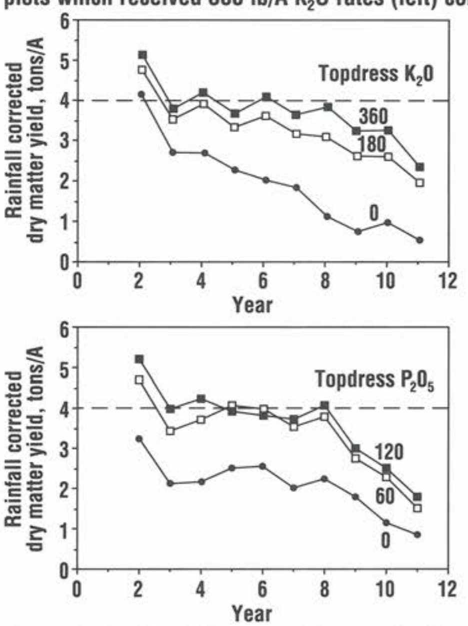


Figure 3. Alfalfa yield corrected for yearly differences in rainfall. Yield was lower when plots received no topdressing. Yield responses of the 180 and 360 lb K_2O/acre treatments gradually separated, suggesting that the value of extra K may not be realized until late in the stand life. The dashed line represents average yield of the best treatment for years 3 through 8.

In 1986, a smaller experiment (within the main experiment) was begun to try and revive the stand which had previously received no K topdressing. Phosphorus was maintained at an adequate level. Surprisingly, when K was applied, alfalfa yields approached those of well fertilized plots. Topdressed K caused the remaining plants (1.5 plants per square foot) to compensate by increasing the number of stems per plant (**Figure 4**). This suggests that stems per plant is the main factor involved in the yield response of thin stands to K.

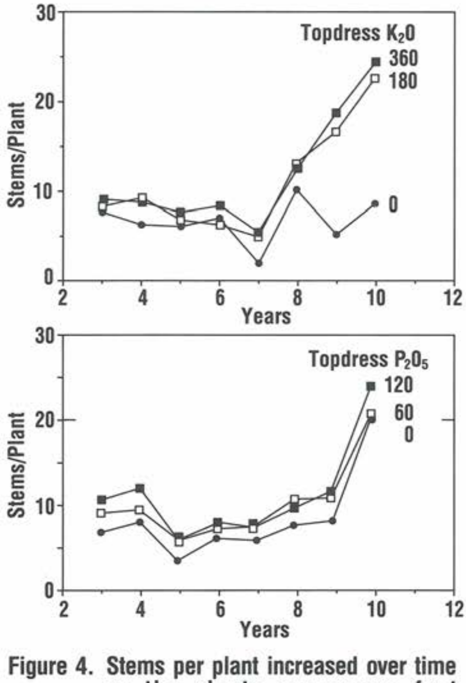


Figure 4. Stems per plant increased over time as the plants per square foot decreased. Note that the plants receiving no annual topdressing generally had fewer stems per plant than plants receiving annual topdressing. As plants thin, K is critical for yield compensation when nearby plants die. There were also more stems per plant with topdressed P, but stems per plant increased with time because of annual K topdressing.

This new information needs to be transferred to plant breeders and crop management specialists. To date, their primary emphasis has been on plants per square foot.

Summary

This research clearly shows that alfalfa properly fertilized with P and K can be maintained economically for long periods of time. The data also show that returns will offset herbicide applications when the alfalfa stands become thin and less competitive. With good P and K fertility, minimal plant density is between 2 and 3 plants per square foot. As farmers look for long-term sustainable programs, well-managed alfalfa can contribute a quality forage to the system. However, the economics of fertilization regimes will be a critical management consideration. Topdressing is vital to persistence. The plowdown treatments help out early in the life of the stand, but do not sustain productivity.

Future assessments of stand condition are likely to place more emphasis on shoots per square foot than on plants per square foot. Not only does K help plants persist, but it promotes shoot growth of remaining plants if a neighboring plant dies, thus maintaining yield potential. ■

"Roots of Plant Nutrition" Conference Proceedings Available from PPI

PROCEEDINGS of the "Roots of Plant Nutrition" Conference are available from the Potash & Phosphate Institute (PPI). The conference, which took place July 8 to 10 in Champaign, IL, was organized by PPI and the Foundation for Agronomic Research (FAR). Co-sponsors included USDA/ARS, Agriculture Canada/Research Branch, USDA/ARS National Soil Tilth Lab, National Fertilizer Environmental Research Center/TVA, and University of Illinois Department of Agronomy.

The Proceedings includes 43 papers presented at the conference, with a variety of topics including "Effect of Nutrients on Root Growth and Ion Uptake," "Tillage and Compaction Effects on Root Distribution," and "Variable Rate Application Systems."

Copies of the Proceedings cost $15.00 each. Send payment to: PPI/FAR Roots Conference, Potash & Phosphate Institute, 2805 Claflin Road, Suite 200, Manhattan, KS 66502. ■

Potash & Phosphate Institute and Foundation for Agronomic Research Announce New Headquarters Location

THE HEADQUARTERS offices of the Potash & Phosphate Institute (PPI) and the Foundation for Agronomic Research (FAR) are moving in August of 1992.

The new office location will be 655 Engineering Drive, Suite 110, Norcross, GA 30092-2821. Beginning August 24, the new telephone number will be (404) 447-0335 and the fax number will be (404) 448-0439. Since 1979, the offices have been located at 2801 Buford Highway, N.E., Atlanta, GA 30329.

"The new location should provide a more efficient facility for the functions of our agronomic research and education programs," noted Dr. David W. Dibb, President of PPI. "We have planned the move to minimize the disruption of services to PPI members, FAR contributors, and others."

Normal operations of PPI and FAR are expected to resume by September 1. ■

Texas Research

Phosphorus Effects on Magnesium Uptake by Forage Grasses

By J.B. Hillard, V.A. Haby, and F.M. Hons

Liming and phosphorus (P) fertilization both increase P concentrations in forage grasses. Texas research also shows that increased P availability leads to higher concentrations of magnesium (Mg) in forage grasses, which may help prevent grass tetany in cattle.

MAGNESIUM is the fourth most abundant cation in the body. Approximately 65 percent of total body Mg is contained in bone. One-third of the Mg in bone is combined with P. Beef cow requirements for Mg are 21, 22, and 18 g/day during early, mid, and late lactation, respectively.

Deficiencies of Mg in the beef cow can occur as a result of low Mg concentrations in forage or supplement. A severe deficiency is associated with the acute metabolic disorder hypomagnesemic tetany, commonly referred to as grass tetany. Grass tetany is most likely to occur in beef cows during initial stages of lactation while grazing forages containing less than 0.2 percent Mg. This research evaluated the effect of P on Mg uptake by annual ryegrass.

Texas Studies

Limestone containing 3.6 percent Mg was applied to whole plots on a pH 4.5 Lilbert loamy fine sand at rates of 0, 600, and 3,400 lb/A (0, 22 and 122 lb Mg/A, respectively). Phosphorus was applied to split plots at rates of 0, 31, 61, 92, 123, 245, and 491 lb P_2O_5/A. Treatments were replicated eight times. These treatments were roto-tilled into a Coastal bermudagrass hay meadow in mid-summer of 1983. A duplicate application of P was surface-applied in June the following year. No additional lime or P treatments were applied after this time. Nitrogen (N), potassium (K), and sulphur (S) were applied uniformly to maintain grass production. Bermudagrass yields were taken in 1983, 1985, and 1986, and ryegrass harvests were made in 1984, 1986, and 1987.

Results

Lime and P rates both significantly increased soil test P levels (**Figure 1**) and must be considered when evaluating the effect of P on Mg uptake in this study. In 1985, soil test P in the 0- to 6-inch soil layer was measured at 38, 40, and 55 ppm, respectively, in response to a total application of 982 lb P_2O_5/A at limestone rates of 0, 600, and 3,400 lb/A. Soil pH was 4.51, 4.65, and 6.19, respectively, in response to the three lime rates. In 1987, with no additional limestone or P applied, soil pH values were 4.5, 4.49, and 4.61. Residual soil P values were lower and similar across lime rates in 1987.

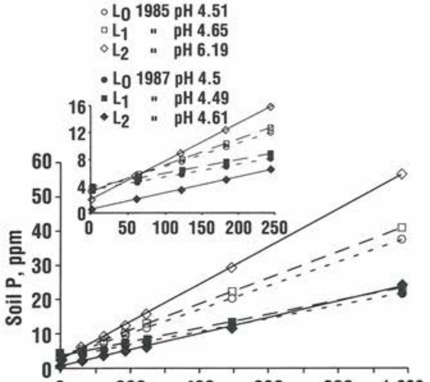


Figure 1. Residual soil P, 2 and 4 years after limestone treatment. L_0 = none, L_1 = 600, and L_2 = 3,400 lb lime/A.

Dr. Hillard is Assistant Professor Soils, Louisiana Tech University, Ruston, LA; Dr. Haby is Professor of Soils, Texas Agricultural Experiment Station, Overton, TX; Dr. Hons is Professor of Soils, Texas Agricultural Experiment Station, College Station, TX.

A detailed view of residual soil P levels affected by P_2O_5 rates from 0 to 245 lb/A is shown with an expanded y-axis superimposed within **Figure 1**. Soil P at the high rate of lime declined significantly between 1985 and 1987 as pH decreased from 6.19 to 4.6. Acidity caused by continued high N application rates and increased uptake of P by larger ryegrass dry matter yields in these limed plots contributed to the decreased levels of residual soil P when compared to the lime check plots (**Figure 2**).

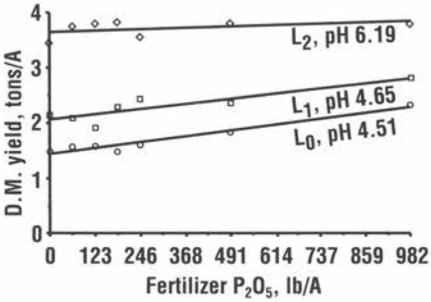


Figure 2. Response of annual ryegrass in 1986 to the interactions of limestone and P fertilizer rates.

The concentration of P and Mg in the ryegrass increased as the level of applied P increased (**Figure 3**). Still, the Mg concentration in all ryegrass samples was well below the adequate forage dietary level (0.2 percent) for beef cattle. Magnesium uptake was associated with P uptake in 'Marshall' ryegrass during 1986 (**Figure 4**). The impaired uptake of Mg in many strongly acid soils is caused by high levels of exchangeable aluminum (Al). Aluminum saturation percentages approximating 70 percent are often associated with Mg nutritional problems in plants. Phosphorus fertilization is known to produce a "lime effect" in acid soils by precipitating exchangeable Al. Higher P fertility may have also produced more extensive root growth to explore the soil for nutrients.

Summary

Proper liming of an acid soil with a dolomitic (Mg) limestone increased soil Mg and increased available soil P levels. Adequate fertilization with P also raised the soil test P level and resulted in increased plant uptake of P. Although these data show that increased P uptake can increase the plant uptake of Mg, the level of Mg in ryegrass remained quite low due to low levels of extractable Mg in the soil. Cattle grazing ryegrass with low Mg concentrations will still need supplemental Mg provided in a mineral mixture to lower susceptibility to grass tetany. ■

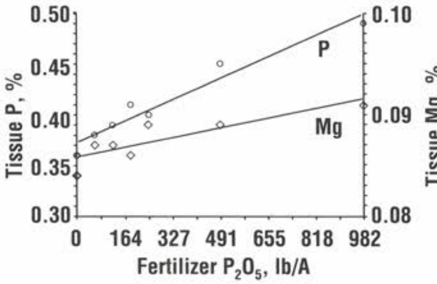


Figure 3. Phosphorus and Mg concentrations in annual ryegrass in 1986 and after P fertilization 2 and 3 years earlier.

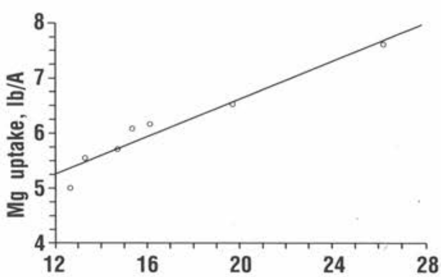


Figure 4. Correlation of the mean uptake levels of P and Mg in annual ryegrass tissue in 1986. (r^2 = 0.86)

In Eastern Canada

Boron Nutrition Studied in Black Spruce Forests

By M.K. Mahendrappa and P.O. Salonius

Boron (B) deficiency may play an important role in growth and development of black spruce stands in eastern Canada. Research is continuing to substantiate possible nutrition problems and treatments.

IN EASTERN CANADA, it is quite common to observe waviness (wobbles) in the expanding terminal shoots of conifers during the early summer months. Such waviness, or sinuosity, is reported as typical signs of B deficiency in radiata pine (*Pinus radiata*) in Australia and New Zealand. In eastern Canada, however, these wobbles disappear during the later part of the year after the secondary growth sets in. This phenomenon can be observed almost anywhere in eastern Canada. During the fast shoot elongation period, temporary deficiency of B is suspected to be partly responsible for the wobble. Possibly due to continuing uptake of B throughout the growth period, the sinuosity corrects itself by the time the new shoot growth starts during the following year.

Other than the possibility that these temporary symptoms are B related, no classical symptoms of B deficiency have been noticed in eastern Canada. Reported here is the unique symptom of premature needle drop in black spruce plantations, related to low levels of B in the foliage and high levels of some other micronutrients associated with the symptom.

SPEED WOBBLE (sinuosity) has been observed in radiata pine with boron deficiency in Australia and New Zealand.

In the northern hemisphere, B nutrition of forest trees is not studied as much as some of the other micronutrients. General symptoms of B deficiency in trees include loss of terminal dominance, multiple shoots (rosette formation), dieback and sinuosity of stems. In forestry, the occurrence of B deficiency appears to be spatially and temporally random and is controlled by several factors. Conventional analysis of plant tissues and soil samples collected at one point in time does not necessarily provide any clues on the status of B nutrition. Numerous factors that affect the occurrence of B deficiency or toxicity symptoms in forest trees are known.

Black spruce (*Picea mariana*) is one of the most important commercial tree species in eastern Canada. In some plantations, from different origins, premature needle loss has been observed in recent years. The loss of only 1-year-old needles is a strange phenomenon which has never been reported or documented before. This condition may be related to B deficiency. It occurred at the time of crown closure in the plantations.

To evaluate the possible causes of this phenomenon, efforts were made to characterize nutrient dynamics in the affected and unaffected trees. Branches of trees were clipped during 1988 shoot expansion

The authors are with Forestry Canada-Maritimes Region, Fredericton, New Brunswick.

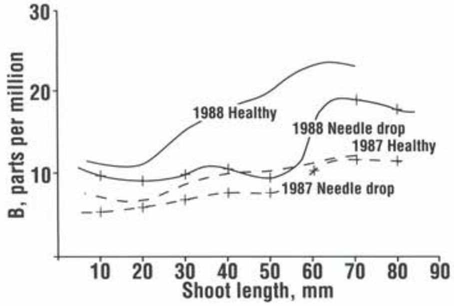


Figure 1. The observed trends in B concentrations in the current (1988) and year-old foliage from a black spruce plantation in eastern Canada.

and the year-old and current foliage were analyzed for nutrients. In most areas with trees exhibiting symptoms, the common factor seems to be low foliar B concentrations (**Figure 1**).

The line graphs in **Figure 1** represent B concentrations in the current and year-old black spruce foliage in healthy trees and in the trees that showed symptoms of premature needle drop. The length of the expanding new shoot plotted on the X-axis represents the growing period starting from the first week of June. Therefore, the data represent the effects of needle age. The solid lines represent B concentrations in the current foliage while the dotted lines represent the data for year-old foliage.

LACK of terminal dominance and rosette formation may be signs of boron deficiency in radiata pine. Necrosis of older needles is associated with rosette formation.

The following conclusions can be drawn from the graph.

- Boron concentrations in the black spruce foliage vary with the needle age and time of the growing period. Thus, it is tenuous to draw any conclusions based on a one-time sampling of foliage.

- The current foliage had a higher B concentration than the year-old foliage throughout the sampling period. Mixing or combining foliage of different age groups will therefore affect the results.

- In the black spruce plantations sampled, the B concentrations were somewhat higher in healthy trees than in the trees that exhibited symptoms of premature needle drop. It should also be noted that the concentrations of aluminum (Al) and manganese (Mn) in the year-old foliage from the trees with premature needle drop symptoms were consistently and significantly higher than in the foliage from the unaffected trees.

In summary, there are suggestions that B deficiency may play an important role in the growth and development of black spruce stands in eastern Canada. None of the classic B deficiency symptoms described in the literature were observed here. Chemical analyses of foliage samples from affected (premature needle drop) and healthy trees suggest the B deficiency may be one of the possible factors responsible for the unique symptoms observed. Boron fertilization work is under way to substantiate these observations and clarify the role of B nutrition in eastern Canadian plantations and its role in causing premature loss of year-old foliage. ■

Texas Research

Chloride Fertilizer Inhibits Leaf Rust in Winter Wheat

By Travis D. Miller

Texas research confirms that chloride (Cl) can suppress leaf diseases in winter wheat. More remains to be learned about the relationship, but Cl fertilization is a part of wheat disease control and yield enhancement.

LEAF RUST (*Puccinia recondita*) is perennially a major threat to winter wheat producers in the southern wheat producing regions of the Great Plains. This disease, to a great extent, limits the area of viable wheat production in Texas and the Gulf Coast. Research in the northern and central Great Plains suggests that Cl fertility has a positive effect on reducing fungal diseases of wheat, including leaf rust. Trials were initiated in the Blacklands of Texas to evaluate the effect of Cl fertility on leaf rust and grain yield during the 1990-91 and 1991-92 growing seasons.

Texas Results

Results have been mixed in Texas trials. In the three 1991 trials, no effect was observed from Cl treatment in two locations, with a slight suppression of rust noted at a third. During the 1992 season, a trial was successfully established near Meridian, TX. Response to applied Cl fertilizers was dramatic, as illustrated in **Table 1**.

Leaf rust in the variety 2158 had almost completely destroyed (80 percent) all leaf area by mid-grain fill in the absence of Cl, while plots treated with Cl fertilizer had significantly more green leaf area during grain fill (see photo). Leaf rust ratings for Cl-treated areas ranged from 5 to 45 percent on May 1, or mid-grain fill. Spring topdressed Cl treatments were appreciably less rust infected than fall treatments. Chloride applied as ammonium chloride (NH_4Cl) appeared to suppress leaf rust more than potassium chloride (KCl) when compared as spring topdress treatments. No difference in leaf rust infection was noted between sources of fertilizer applied in the fall.

Table 1. The effect of chloride fertilizer source and time of application on leaf rust infection of winter wheat. Meridian, TX. 1992.

Fertilizer source	Rate, Cl lb/A	Time applied	Leaf rust rating, % 5/1/92
NH_4Cl	40	Feekes 5.0	5
NH_4Cl	40	Preplant	45
KCl	40	Feekes 5.0	30
KCl	40	Preplant	45
Check[1]	0	--	80

[1]All plots were treated with 100 lb/A 18-46-0 preplant incorporated, 100 lb/A 32-0-0 on 2/15/92 and 147 lb/A 34-0-0 on 3/11/92.

While many factors remain to be studied at this time regarding the dramatic suppression of leaf rust in 1992 and the apparent failure of Cl to suppress leaf rust at 2 of 3 sites in 1991, several key differences can be noted. These include:

Variety. The variety 2158 was strongly affected by Cl treatments, in 1992. It was not evaluated in 1991. This is consistent with data from other researchers who report a strong interaction between Cl response and variety.

Rainfall. The 1992 site received more than 30 inches of rain between preplant and spring topdress treatments. This may have leached much of the available Cl fertilizer

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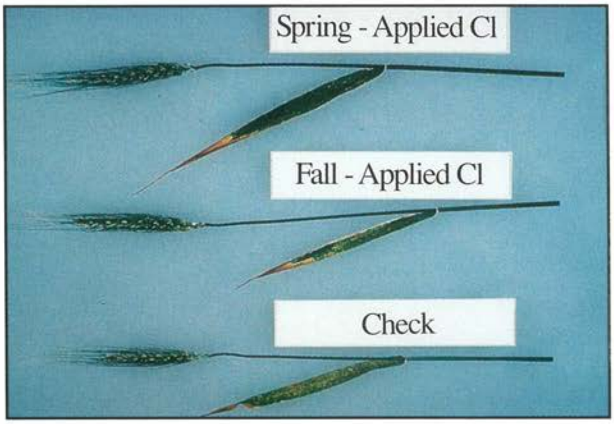

WHEAT plots treated with chloride fertilizer had significantly more green leaf area during grain fill than untreated plots. Spring topdressed treatments were less infected with rust than fall treatments.

from the profile, resulting in significant deficiencies between fall and spring treatments. High rainfall could also have enhanced the environment for disease.

Soil test Cl levels. Sites in 1991 measured 3 to 5 parts per million (ppm) Cl in the surface 2 feet of soil. The 1992 site tested less than 1 ppm Cl.

Conclusions

Chloride fertilizers can suppress leaf rust in winter wheat in Texas. Results are not entirely consistent or predictable, but Cl fertility can provide an economical suppression of leaf rust under some growing conditions. ■

Missouri

Potassium May Affect Alfalfa Susceptibility to Insect Damage

RESEARCHERS have studies on an established pure stand of alfalfa to determine the effect of potassium (K) sources on the susceptibility of alfalfa to insects and diseases.

The 1991 data indicate that statistically significant differences in insect numbers do exist among various K fertility treatments when insect numbers reach or exceed economic threshold levels.

Data indicated that recommended rates of potassium-magnesium sulphate ($K_2SO_4{\cdot}2MgSO_4$) reduced numbers of alfalfa weevil larvae by 31 and 49 percent for Julian dates 100 and 114, respectively. Larvae numbers were reduced by 50 and 59 percent, respectively, with recommended potassium chloride (KCl) rates on the same dates. Potassium sulphate (K_2SO_4) at recommended rates reduced alfalfa weevil larvae by 27 and 34 percent, respectively.

While it appears that alfalfa weevil are in some way suppressed by better K nutrition, potato leafhopper did not show the same response. There were no apparent relationships among K sources and foliar disease symptoms at this early stage of experimentation. ■

Source: W. C. Bailey, J. T. English, and J. R. Brown. 1992. The effect of potassium-magnesium sulphate upon the susceptibility of alfalfa to insect, disease, and nutritional problems. Agronomy Misc. Publ. 92-01, Dept. of Agronomy, Univ. of Missouri, Feb. 1992. p. 168-182.

Nutrient Assessment and Distribution of Animal Manure

By J.P. Zublena and J.C. Barker

Assessment of manure nutrient content in North Carolina indicates that this important source can represent substantial percentages of plant nutrient requirements in certain areas of the state.

NORTH CAROLINA is one of the leading states in animal production. Trends in this industry towards production consolidation and intensification, while sound from an economic and management perspective, can create a potentially significant negative environmental impact from large amounts of animal manures.

A nutrient assessment project was initiated to: 1) assess current generation of manure by county, 2) determine amounts of nutrients from manure that could be made available to agronomic crops, 3) determine the quantity of nutrients required in each county, 4) determine the amount of nutrients purchased in each county, 5) calculate the percent of agronomic crop nutrients that could be supplied by animal manure, and 6) determine the nutrient balance in each county after animal manure and purchased nutrients are considered.

The Situation

In 1989, approximately 20.7 million tons of animal manure were generated in North Carolina. Because many animals are not confined, only about 52 percent of the manure can be collected for use. Manures in 1989 contained the equivalent of 158,000 tons of nitrogen (N), 108,000 tons of phosphate (P_2O_5), and 101,000 tons of potash (K_2O). Quantities of other nutrients were also measured.

Some nutrients are not released from manure during the first year after application, while others are lost in storage or in the field due to volatilization, leaching, or denitrification. We estimated that only 20 percent (31,846 tons/year) of the N, 40 percent (42,912 tons/year) of the P_2O_5, and 29 percent (29,795 tons/year) of the K_2O were available for plant usage. Considering the statewide nutrient requirements of agronomic crops and pasture and the plant-available nutrients from manures, 15 percent of N, 55 percent of P_2O_5 and 39 percent of K_2O requirements could be met with manures. Manure would provide all P_2O_5 requirements for agronomic crops (except legumes) in 13 counties and all K_2O requirements in 8 counties.

Commercial fertilizer sales data were considered in assessing county nutrient balances. These data may reflect some bias because fertilizers purchased in one county may be used in another. However, based on this input, approximately 23, 19 and 25 percent of the counties had surplus quantities of N, P_2O_5, and K_2O, respectively, utilizing a crop base excluding legumes.

This assessment is being used by the North Carolina Cooperative Extension Service to focus and network educational efforts on animal waste management where there is the greatest need. Extension

(continued on page 31)

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Maximum Economic Yield and the Farmer . . . One Dealer's Experience with an MEY Club

By Henry Neutens and Mark D. Stauffer

Maximum economic yield (MEY) is alive and well. Although some consider the 1980s concept of 'more' crop production to be outmoded and not applicable in the 1990s, progressive farmers are realizing the economic advantage of producing more bushels per acre.

WHAT has dealer and farmer emphasis on MEY taught us? The best bottom line results when best management practices (BMPs) are integrated. Yield responses defined in maximum yield research (MYR) trials throughout North America (**Table 1**) identified BMPs such as:

- hybrid/variety selection
- weed, disease and insect management
- soil fertility requirements
- tillage systems
- plant populations
- planting dates.

These are critical inputs for crop production efficiency.

Dealers and farmers also challenged these yield barriers and learned the valuable lesson that good management through balanced and adequate inputs increased crop yields. Economists indicate that MEY is often 90 to 95 percent of **maximum yield**. Progressive farmers and dealers continue to actively pursue this goal.

One Dealer's Experience

Kent County Fertilizers, in cooperation with six farmers, started an MYR Club in 1980 after recognizing that corn growers in the heart of Ontario's corn belt had to improve to stay competitive. During the period 1981 to 1986, club members achieved yields as high as 198 bu/A. They established these ideas:

- Phosphorus (P) and potassium (K) soil tests below the 5-inch depth were not raised by greater than normal fertilizer application rates.
- Plant populations were often inadequate and corn hybrid x population interactions affected yields.
- Row widths varying between 30 and 38 inches had no effect on yield.

Subsequently, the Club re-directed its effort to focus on MEY while re-doubling its membership several times. Data from the first 5 years (1987-1991) of club activities are summarized in this article.

BMPs Help Stabilize Corn Yields

MEY Club corn yields were higher and more stable than average yields for

Table 1. Maximum yield research records for North America.

Crop	Yield/location USA	Yield/location Canada
Corn, bu/A	338/New Jersey	293/Ontario
Soybeans, bu/A	118/New Jersey	96/Ontario
Wheat, bu/A	216/Washington	205/British Columbia
Alfalfa, tons/A/year	24/Arizona	9.7/Ontario

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Table 2. Corn and soybean yields and growing season conditions.

Year	Yield[1] MEY[2]	Yield[1] County	Row width, in.	Average dates Planted	Average dates Harvested	Harvest population, (000)	Rain, in.
	------ bu/A ------						
1987	158	135	36	May 3	Oct. 24	26.8	19.6
1988	143	92	36	May 3	Oct. 19	24.7	11.3
1989	147	132	36	May 6	Oct. 30	25.3	15.3
1990	143	132	36	May 6	Nov. 9	24.9	22.3
1991	145	95	35	May 8	Oct. 14	26.3	8.9

[1]Average yields. Sources: MEY club data and OMAF Policy Analysis Branch.
[2]Selected 2 acre sites from MEY fields. Number of farmers in the corn club are 32, 39, 46, 32, and 23, respectively, for the 5 years.

the county. The average county yield for corn between 1987 and 1991 was 117 bu/A, compared to the MEY Club average of 145 bu/A (**Table 2**). Corn yields varied over the 5-year period and particularly during the drought years of 1988 and 1991. A major benefit accruing to MEY Club members was the yield stability BMPs provide. Annual Club yields ranged from −3 percent to +7 percent of the 5-year Club average. Annual county yields varied between −21 percent and +15 percent of the 5-year county average.

Planting dates over the 5-year period ranged from as early as April 22 to as late as May 20. For each day of delay in planting after April 22, yield was reduced by 1.06 bu/A.

Plant population at harvest data substantiated what earlier MYR in Ontario revealed–that farmers in the area traditionally underplant corn by about 10 percent. The MEY Club data indicate that corn yields increased 1.6 bu/A for each 1,000 harvested plants/A as populations increased from 18,200 to 31,500.

Crop rotation practices benefitted both crop yield and the environment. Corn yields were greatest following soybeans, slightly less following wheat and much less in a corn-corn rotation (**Figure 1**).

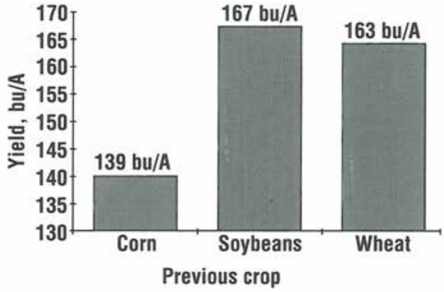

Figure 1. Effect of previous crop on corn yield (5-year average).

The 172 farm-years of data generated by the MEY Club provide these growers with regionally specific corn production guides. Equally valuable is the knowledge gained in understanding relationships between various management practices and crop yield.

Fertilizer Management– A Key to High Yields

Good soil fertility and adequate, balanced fertilizer management coupled with other BMPs helped boost Club yields. Higher yields resulted when more nitrogen (N), P, and K were available (**Table 3**). Top yields are most efficiently produced when nutrient supplies are bal-

Table 3. Fertilizer nutrient rates and BMPs associated with each yield category (average 1987-1991).

Yield category, bu/A	Yield, bu/A	Row width, in.	Plant date	Harvest population	Nutrient Applied N	Nutrient Applied P_2O_5	Nutrient Applied K_2O	Nutrient Applied Zn
					----------	lb/A	----------	
80-120	103	36	May 7	25,875	173	50	89	1
121-160	142	36	May 5	25,842	181	53	97	1
161+	171	35	May 2	27,184	198	63	107	1

anced. Soil test P and K values were high for all three yield categories (**Table 4**).

Table 4. Soil test levels for P and K for each yield category.

Yield category, bu/A	Average yield, bu/A	Soil test values P	K
		------ ppm	-------
80-120	103	162	289
121-160	142	115	189
161+	171	119	254

Adequate and Balanced Nutrition for Most Efficient Yields

High yielding corn requires more total nutrients, but often those nutrients are used more efficiently because of the presence of adequate amounts of each nutrient and the utilization of other BMPs. Previous research has shown that nutrient uptake per unit of production for MEY corn is remarkably stable, suggesting a lack of luxury consumption with high nutrient availability. Split nutrient applications, particularly N, can have dramatic effects on N use efficiency as can the presence of adequate amounts of P and K.

Data from the Kent County MEY Club indicate that production in the highest yield category (161 bu/A up) required only 1.2 lb N/bu of grain compared to 1.7 lb of N/bu in the 80 to 120/A yield range. Continuing as one of the challenges of MEY production is to better understand fertilizer placement and timing effects on plant nutrient uptake and nutrient interactions.

MEY and Economic Sustainability

Top corn producers in the Kent County MEY Club verified the principle of MEY . . . that highest profits result when high yields are achieved (**Table 5**). Highest profits resulted when BMPs were integrated into effective and efficient production systems. These 172 farm-years of data indicate that highest yields were associated with substantially lowered production costs per bushel, a greatly elevated gross return and significantly higher net profits.

Clearly, the integration of BMPs into an MEY production system provided for all of the targeted aspects of crop production . . . higher input efficiency, reduced per unit production costs, higher overall profitability, and improved farm economic sustainability. The Kent County MEY Club members benefited from their mutual experiences and the sharing of knowledge that such joint activities generate. ■

Table 5. Production costs and net return summary for MEY Club corn production.

Yield category, bu/A	Average yield, bu/A	Production cost $/A	Production cost $/bu	Gross return @ $2.60/bu, $/A	Net profit (no land cost) $/A	Net profit (no land cost) $/bu
80-120	103	228	2.22	269	41	0.38
121-160	142	240	1.70	370	130	0.90
161+	171	231	1.36	445	213	1.24

Cost of land is excluded from the calculation.

Nutrient Assessment . . . from page 28

agents are being encouraged to include manure management in their plans of work and to share this information with their county commissioners and advisory boards.

Extension agents are being encouraged to use the animal distribution maps that were developed to initiate discussions with livestock and poultry producers on the need to consider dispersing livestock operations to prevent "clustering" of animal units that might serve as point sources of water contamination if they exceed the crop nutrient needs of the area.

Meetings with the fertilizer industry are being conducted to discuss the potential impact of these findings on sales and to explore opportunities for incorporating organic sources into existing fertilizer operations. ■

Be Optimistic

There is a prevailing mood of pessimism throughout much of the world. Crime in the streets and in public office, unbalanced budgets, growing unemployment—all while world population increases by 250,000 each day.

Even farmers, optimistic by nature, are worried and discouraged.

Well, after all, conditions *are* bad; shouldn't we be pessimistic?

Absolutely not! Fundamentally, the world has every reason to be better off today than at any other time in history.

In the fields of health and medicine the advances are truly fantastic. Developments in energy and transportation are unbelievable. Opportunities abound for learning and education.

On the farm front we live in the best of times. Consider the marvels of science and technology that can make farm life challenging and rewarding—modern farm equipment and farm chemicals that feed plants and animals and protect them from weeds, diseases, and pests. Genetic engineering gives us plants that are more nutritious and higher yielding.

Yes, there is every reason for optimism. We have the know-how today to feed the 8 billion people expected in the world by 2030. The problems we face are largely self-created. Crime, bad government, mismanagement, and greed are all of our own making. The basics for happiness and prosperity have been given to us. They are all there. It's up to us to use them properly.

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