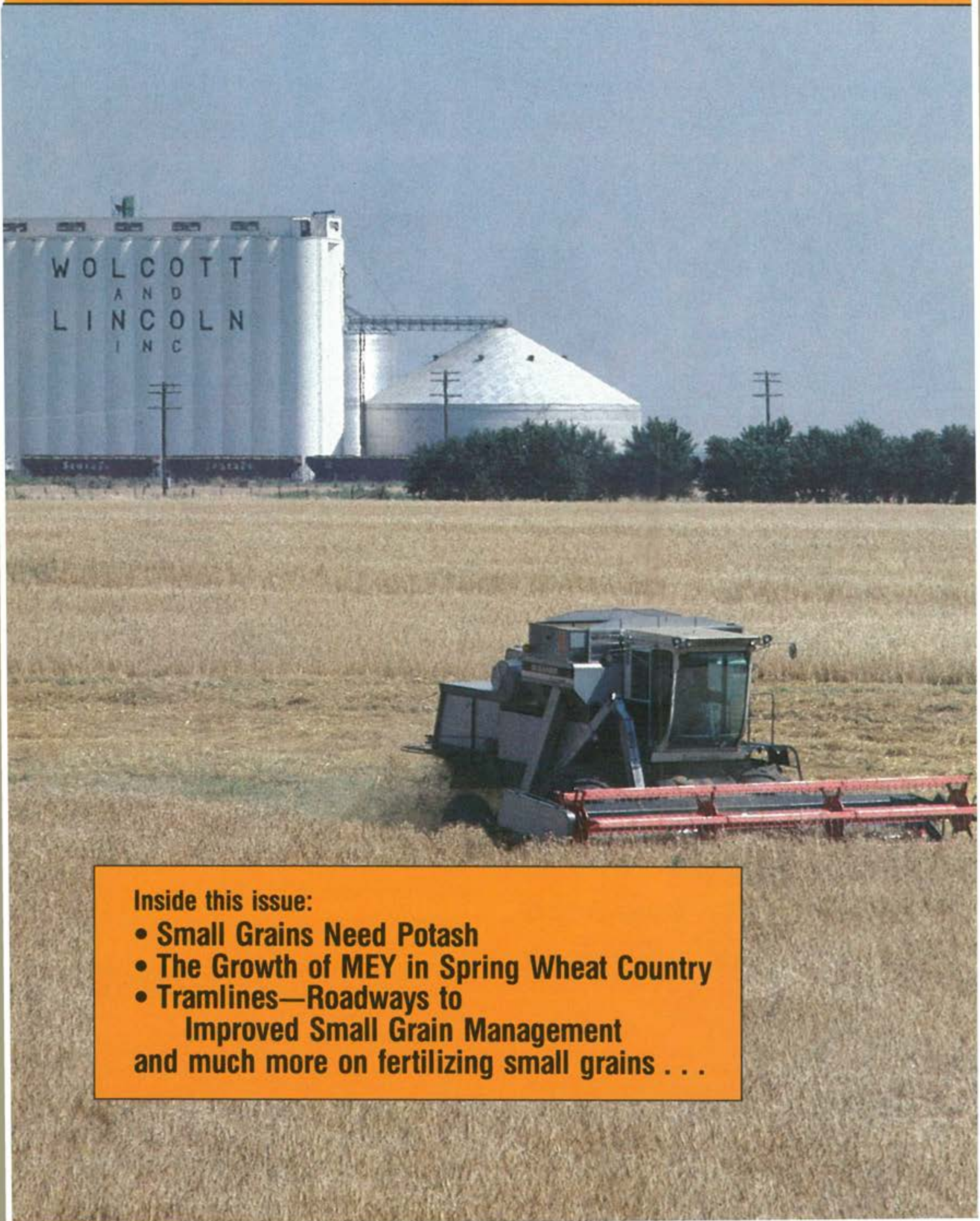
BETTER CROPS

with plant food

Summer 1987



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BETTER CROPS with plant food

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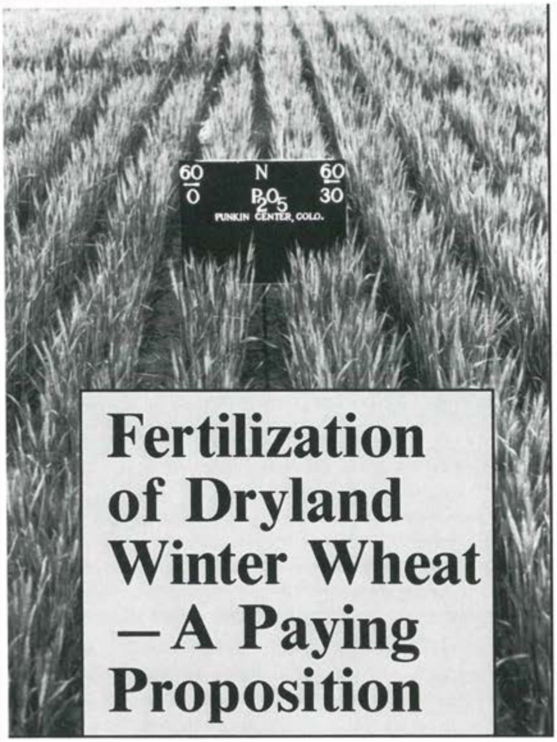
Photo courtesy of *Farm Journal*.



Fertilization of Dryland Winter Wheat —A Paying Proposition

By Dwayne Westfall and Hunter Follett

Dryland winter wheat producers in the western Great Plains have gained a new interest in fertilizing their crops. Estimates in 1978 show less than 5% of the acreage was fertilized with any form of fertilizer. Currently, over 65% of the acreage receives N. Phosphorus fertilization is still in its infancy in the western Great Plains region. It is estimated that less than 15% of the total acreage receives P fertilizer.

The question arises, "Which fields will respond to N and/or P fertilizer?" Use of calibrated soil tests is the best way to answer the question. The application of N or P fertilizer to fields that have adequate nutrient availability results in no return to fertilizer dollar input. Conversely, proper fertilization of fields that are deficient in N or P will result in large returns to fertilizer dollar input. Soil testing, in conjunction with a proper fertilizer management program, is the key to obtaining maximum economic yields of dryland winter wheat.

NITROGEN (N) FERTILIZER experiments have been conducted at 66 locations since 1981. Sixty-four percent **(Table 1)** of these sites responded to N fertilizer with yield increases ranging from 6 to 20 bu/A. Average grain yield response at the 66 sites was 12 bu/A, as a result of N application. The magnitude of response to each increment of N fertilizer is shown in **Figure 1.** Yield response did not maximize until the 60 lb N/A rate was exceeded.

Table 1. Response of dryland winter wheat to N fertilizer.

Year	Total Sites	Site Response to N No.	%	Yield Increase Range	Average —(bu/A)—
81-82	17	12	71	5-28	14
82-83	19	10	53	6-19	12
83-84	—	—	—	—	—
84-85	18	12	67	6-21	12
85-86	12	8	67	5-12	10
Summary	66	42	64	6-20	12

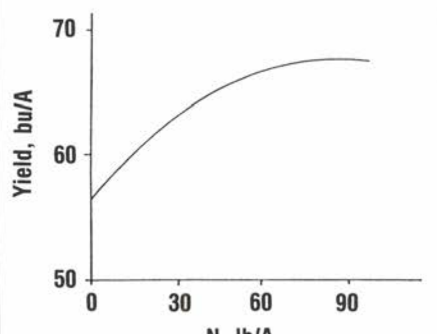


Figure 1. Yield response of dryland winter wheat to N fertilizer. (Colorado)

Application of the first 30 lb N/A resulted in a 9 bu/A increase in yield. An increase of 0.4% in protein content also occurred with the 30 lb N/A application **(Figure 2).** The increase in protein as a function of N fertilizer application was linear. High-protein wheat often brings a premium price in the marketplace.

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The authors are with the Department of Agronomy, Colorado State University.

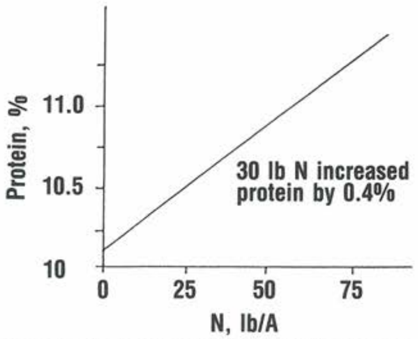

Figure 2. The relationship between N rate and grain protein content. (Colorado)

Protein content has also been shown to be a post-harvest indicator of N sufficiency of winter wheat. This relationship is shown in **Table 2.** If the protein content is less than 11.1%, it is likely that yields were limited by an N deficiency. Application of N fertilizer would probably increase yields and protein content. In the range of 11.1 to 12.0% protein, the probability of N limiting grain yield is much smaller. Applying N fertilizer may not increase yield, but it is likely that it would increase protein content. When the protein content is greater than 12%, N availability is probably not limiting yield but would still increase protein content. Grain protein as a post-harvest indicator of N sufficiency is an educational tool. Farmers usually know if a field produces "high" or "low" protein content grain. Thus, the criteria presented in **Table 2** can be used to show the farmers their probable need to alter their N fertilizer management program. A proper N management program is vital if growers are to achieve maximum economic yields and produce wheat of good milling and baking quality.

P Fertilization

Winter wheat growers have not adopted good P fertilizer management practices as rapidly as N fertilization. Phosphorus fertility studies have been conducted at 64 sites since 1981 **(Table 3).** The actual application rates used in these studies were 60 and 120 lb P_2O_5/A broadcast on the soil surface before planting with no additional incorporation. Other research we have conducted has shown that the relationship between broadcast and incorporated P is 3:1. Therefore, 60 and 120 lb broadcast is equivalent to 20 and 40 lb P_2O_5 incorporated. Incorporation equivalents are used throughout this discussion. Thirty-three percent of these sites responded to P fertilizer, ranging in yield response from 2.4 to 16.3 bu/A. The average yield response

Table 3. Response of dryland winter wheat to P fertilizer.

Year	Total Sites	Site Response to P		Yield Increase	
		No.	%	Range —(bu/A)—	Average
81-82	3	2	—	4.7- 6.1	5.4
82-83	19	6	32	2.4- 8.5	4.7
83-84	17	2	12	2.7- 3.6	3.2
84-85	18	7	39	2.8-16.3	4.8
85-86	7	4	57	5.0-12.3	7.8
Summary	64	21	33	3.5- 9.4	5.2

Table 2. Guidelines for interpreting dryland winter wheat grain protein-nitrogen levels.

Protein level	Interpretation
Less than 11.1%	Yields may be significantly limited by nitrogen deficiency. More nitrogen fertilizer would probably increase yields and protein content.
11.1-12.0%	Yields may have been limited by nitrogen deficiency. Applying more nitrogen fertilizer may not increase yield but will increase protein content.
Greater than 12.0%	Yields were probably not limited by nitrogen deficiency. Application of more nitrogen probably will not increase yield but will increase protein content.

Source: R.J. Goos, et al.

to P has been 5.2 bu/A; much smaller than the 12 bu/A average yield increase observed with N fertilization. The maximum yield response usually occurs with the application of about 40 lb P_2O_5/A broadcast-incorporated applied on low soil testing P fields. When soil-test P is at the high end of the medium range or greater, the probability of a yield increase is small.

Proper placement of P is very important and the effectiveness of different placements is dependent upon soil-test P level. On low P soil testing fields, the advantage of row application to broadcast-incorporated application may be as great as 3:1. This means that three times as much P applied broadcast-incorporated is required to produce the same yield response as a given amount of P row-applied with the seed. On medium soil test level soils, this advantage decreases markedly and there may be no advantage to applying P fertilizer in the row as compared to broadcast. Work in several states has shown that knifing P prior to planting, application with the seed, and dribbling the P directly over the row were all equal in terms of yield response. Dual N-P application is a good method of application and under certain conditions may result in higher P uptake and yield than other methods.

Phosphorus fertilizer applied on the surface and left unincorporated is a very inefficient method of application. Three or four times as much P may be needed to get the same yield response as incorporated P. As can be seen from the results cited above, proper P placement is critical to efficient fertilizer use.

N And P Fertilizer Interactions

The interaction between N and P availability on plant growth has been documented. This interaction is often highly visible on dryland winter wheat. Yield response to N fertilizer will be limited if the P requirement of the crop is not satisfied. This interaction is shown in **Figure 3,** which is the average of data from 9 experiments conducted on P-deficient soils. The application of 60 lb N and no P_2O_5 resulted in no significant increase in yield as compared to no N fertilizer. However, when 20 or 40 lb P_2O_5/A was applied with the N, a yield increase of about 4 bu/A was obtained. This graphic representation of the interaction of N and P fertilizer on dryland winter wheat yields demonstrates the need for proper use of P fertilizer and the interdependence of N response on P availability, if P is a yield-limiting nutrient.

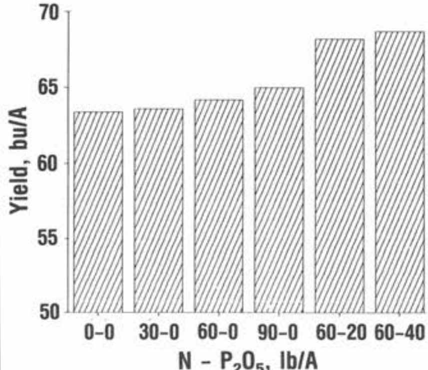

Figure 3. The interaction of N and P fertilization on wheat yield. (Colorado)

Summary

Proper use of N and P fertilizer is necessary to maximize profits in the production of dryland winter wheat. Soil testing is a key step in determining which fields should be fertilized and which fields will not give an economic return to fertilizer dollar input. Approximately 65% of the fields in eastern Colorado are deficient in N and should receive N fertilizer. Approximately 33% of the fields are deficient in P. Grain yield responses to P average about 5.2 bu/A, while responses to N have averaged 12 bu/A. If P is limiting growth, the maximum response to N fertilizer will not occur. The proper rates of both N and P are necessary for maximum economic yields and good milling and baking quality of dryland winter wheat in the western Great Plains region. ■

The Growth of MEY in Spring Wheat Country

By E.H. Vasey, Don Kenna, Gary Walter, and Chuck Rongen

One of the most popular agricultural topics recently in North Dakota and western Minnesota has been MEY. MEY describes more intensive, higher profit management, and spring wheat growers want to know more about it. This article relates the background and reasons for the current strong interest in MEY.

IN THE LATE 1970s, the Potash & Phosphate Institute (PPI) began funding maximum yield research (MYR) projects in many regions. And the Foundation for Agronomic Research (FAR) increased the emphasis beginning in 1980.

North Dakota received MYR funds for work on wheat in 1980. In 1981-82, a MEY type of computer software was field-tested by extension and research staff. The North Dakota Extension Service plan of work for 1984-87 included MEY under a heading of Profitable Crop Production.

Key Groups

Four major groups have been involved in this MEY effort: North Dakota Extension Service; North Dakota Agricultural Association; agribusiness; and producers. The involvement of each group is outlined in the following sections.

North Dakota Agricultural Association (NDAA)

In the mid-1980s a series of events triggered interest in MEY wheat production, beginning in 1984 when NDAA learned of the Landmark High Yield Wheat Club in Manitoba. In 1985 several producers grew outstanding yields, showing that 100+ bu/A wheat was possible. A computer software package, WHEAT-PAC, was developed by North Dakota Extension Service scientists to further stir interest.

In 1986 during a regional MEY workshop, NDAA sponsored a discussion session on formation of MEY clubs, then held a kickoff meeting at its annual show in November. About 175 people attended the session which resulted in 60 MEY start-up kits being sent out to interested contacts in the Dakotas, Minnesota, Montana, and Manitoba.

By April of 1987, 32 clubs involving 350 members were in place. After seeding, interest picked up again with as many as 25 inquiries per week being received by NDAA. The program has gotten excellent news coverage, and the future continues to look bright. NDAA has invested in a computer to handle MEY Club records and is cooperating with other agencies in developing software to summarize MEY Club and Test-20 (National Association of Wheat Growers test plots) nationwide.

North Dakota Extension Service (NDES)

Extension personnel have worked hard to gain media attention for MEY activities. Results have been successful.

The MEY approach has stimulated new foliar N application research. The success of the regional MEY workshops is leading to more interest among state and county Extension personnel. NDES programs through 1991,

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including training, are focusing heavily on MEY concepts.

In cooperation with NDAA, PPI and FAR, another regional workshop is planned for January, 1988. New video and computer educational packets are being planned and developed. A network of MEY resource persons is being developed for use in future educational efforts.

Extension personnel are collecting feedback from MEY sponsors and producers which will be used by an advisory council to determine future needs for MEY activities.

Agribusiness

Experience shows local agribusiness sponsors are key to MEY club establishment and development. Agribusiness and producers working together, sharing in the planning process, create better communicative and improved business relationships.

Agribusiness benefits because interest in new products has been stimulated. Some firms have added a whole new line of "MEY Club" equipment, including rain gauges, soil probes, etc.

Producers (MEY Club Members)

Producers are proud to be a part of the MEY effort, some contributing as much as $200 in dues to finance club activities. They have willingly participated in radio, TV and press interviews. They are sharing information and interests as they team together.

MANY WHEAT GROWERS are participating in local MEY groups to improve their management systems. Larry Richard, shown here, is president of the "Bottomline Club" in Cass County, North Dakota.
(Photo courtesy *Farm and Ranch Guide.*)

Producers attend meetings and ask challenging questions and expect answers from the experts. They are learning more about plant development, diseases, nutrition and how these factors impact their management decisions.

The producer members stimulate local news coverage of MEY wheat production, and several have agreed to serve as resource persons for the workshop next January.

Innovations in equipment are being shared. Producers are interfacing weather information to computer programs to track growth stage as a management tool. Reference materials from MEY workshops are being made available to other producers via the computer.

Summary

MEY clubs are springing up across the Plains of the U.S. and Canada, assisted greatly by maximum yield research at the North Dakota Agricultural Experiment Station. Early support from the Landmark High Yield Wheat Club in Manitoba has been a significant contribution. Information provided by the National Association of Wheat Growers Foundation through their Test-20 program has further stimulated interest. Grants from PPI and FAR have helped financially.

Research information from USDA-ARS scientists at Mandan, ND, has been key to the success of MEY efforts, as has been support from agribusiness. In the final analysis, however, the 350+ wheat growers dedicated to finding better ways have been the backbone of the program. It is an exciting time in the Northern Plains . . . and MEY is a big part of the reason why. Watch for updates on its future growth. ■

MEY

Fertilizing Small Grains for Profitable Production in Rotation Systems

By R.G. Hoeft, L.V. Boone, H.F. Reetz

In the Midwest, farmers often grow wheat or other small grains as part of a rotation system with corn or soybeans as the main crops. Important fertility considerations for small grains may be overlooked.

A GOOD PLAN for managing soil fertility includes building soil test levels required to produce optimum yields for all crops in the rotation, then replacing nutrients removed or lost as part of the production system.

Crop Removal

Nutrient uptake by corn, soybeans and wheat is shown in **Table 1.** These data represent the major nutrients in aboveground portions of the crop, including grain. The soil fertility level must be high enough to meet these needs for each crop.

The fertility program must also provide for replacing nutrients actually removed in the harvested crop. Approximate removal rates are shown in **Table 2.**

Table 1. Plant food uptake (PFU) of corn, soybeans and wheat.

Crop	Yield/ Acre	Nutrient Uptake, lb/A**				
		N	P_2O_5	K_2O	Mg	S
Corn	120 bu	160	68	160	39	20
	160 bu	213	91	213	52	26
	200 bu	266	114	266	65	33
Soybeans*	40 bu	224	38	144	16	14
	60 bu	315	58	205	24	20
	80 bu	416	78	250	32	26
Wheat	50 bu	94	34	102	15	13
	75 bu	141	51	152	23	19
	100 bu	188	68	203	30	25

*Legumes get most of their nitrogen from the air
**Figures given are total amounts taken up by the crop in both the harvested and the aboveground unharvested portions. These numbers are estimates for indicated yield levels, taken from research studies, and should be used only as general guidelines.

Table 2. Plant food removed in harvested grain.

Crop Grown	lb/bu		
	N	P_2O_5	K_2O
Corn	0.75	.44	0.29
Soybeans	4.00	.80	1.40
Wheat	1.15	.55	0.34

Soil Test

Soil tests are essential to a sound fertility management plan. Soil test levels should be maintained at slightly above the level at which optimum yield would be expected. University of Illinois guidelines suggest that phosphorus be applied up to P_1 values of 60, 65, or 70 lb/A available P, respectively, for high, medium, and low phosphorus-supplying soils. Similarly, they suggest that at least maintenance potassium be applied when soil K test levels are below 360 and 400 lb/A available K for low and high cation-exchange-capacity soils. If high K removal crops such as corn silage or alfalfa hay are grown in the rotation, higher soil test levels and/or more frequent testing may be necessary. When soil tests are between 400 and 600 lb/A available K, and corn silage or alfalfa are grown in the rotation, soil tests should be taken every 2 years, or maintenance levels of K should be added to ensure that soil test levels do not fall below the point of optimum yields.

Dr. Hoeft and Mr. Boone are Extension Agronomists, University of Illinois, Urbana, IL; Dr. Reetz is Westcentral Director, Potash & Phosphate Institute, Monticello, IL.

Nitrogen

Recommendations for N application on wheat and other small grains are dependent upon soil type, crop variety, and future cropping intentions. Deep, dark-colored, high organic matter soils usually require less total N than light-colored soils. Illinois recommendations for N on wheat range from 50-70 lb/A N for deep, dark colored soils, to 90-110 lb/A N for low organic matter soils with a low N supplying capacity. Rates may be adjusted upward for higher yield levels if the varieties grown can tolerate higher N rates without lodging.

Most wheat varieties now grown have been selected for improved standability and can withstand higher N rates without suffering from N-induced lodging. When small grains are used as a cover crop to establish legumes and grasses, the N application should be reduced to slow vegetative growth of the small grain and allow the forage seedlings a better chance to grow.

Timing. Nitrogen requirement in the fall is relatively small, but some farmers prefer to apply all of the N requirement in the fall to avoid potential problems of muddy fields and late application in a wet spring. Use of a nitrification inhibitor is suggested if all of the N is applied in the fall. As an alternative, a small portion of the total N may be applied in the fall and the remainder applied as a spring topdress treatment.

Phosphorus

Research has shown that, as an average for Illinois soils, 9 lb/A of P_2O_5 would be required to increase the P_1 soil test by one pound. However, the actual buildup rate will differ considerably for different soils, so soil type and local information on rate of soil test increase for the given soils must be considered. Frequent soil testing and careful records of fertilizer applications and crop removal are essential to developing a sound soil fertility plan.

The P soil test level required for optimum yields of wheat and oats is considerably higher than for corn and soybeans **(Figure 1),** partly because of the difference in uptake patterns for wheat and corn. Wheat requires a large amount of readily available P in the fall, when the root system is small and is feeding primarily from near the soil surface. Thus, a higher soil test is required than for corn, which takes up larger amounts of P later in the season when roots are feeding from lower in the soil profile. Also small grains are growing when soils are cooler and phosphorus diffusion rates are slowed.

To compensate for the higher requirements of wheat and oats, it is suggested that P fertilizer be applied prior to seeding at 1.5 times the expected removal rate. This will help ensure a ready supply of P and will help maintain the optimum level for the rotation.

Potassium

Small grains have a generally lower potassium requirement than that for corn and soybeans **(Figure 2),** so when planning the fertility program, the requirements for the corn and soybean crops in

(continued on page 11)

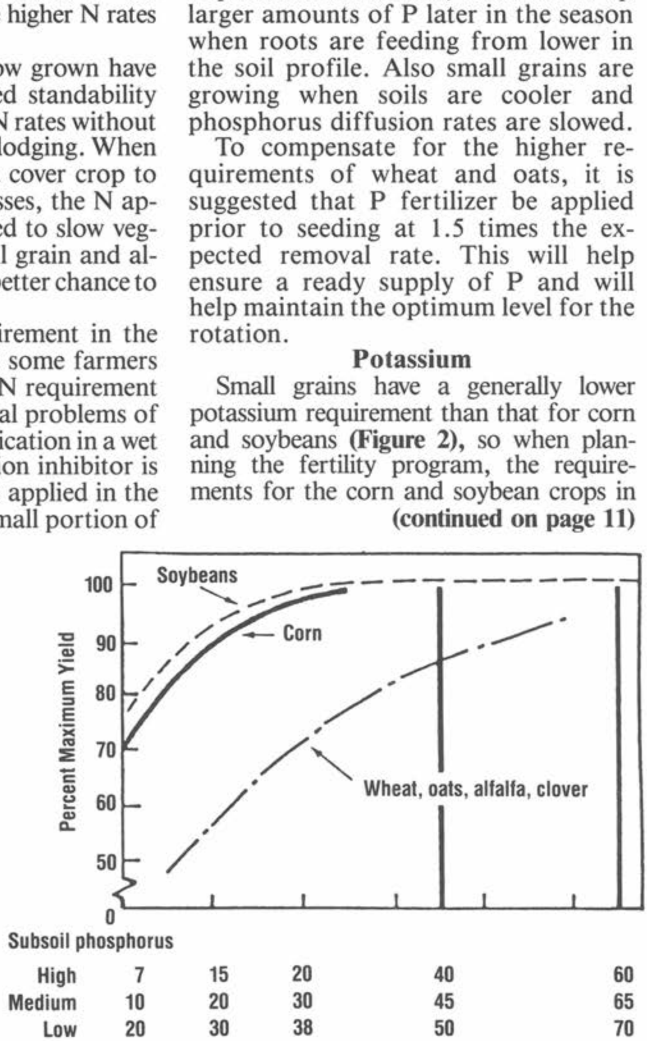

Figure 1. Relationship between expected yield and soil-test phosphorus (P). (University of Illinois response curve).

Small Grains Need Potash

By G. Walt Wallingford

Wheat and other small grains take up large amounts of potash from the soil. On responsive soils . . . usually those testing low or medium in K . . . potash offers an opportunity for increased profits. It also strengthens the straw and cuts down on lodging.

HIGH YIELD RESEARCH shows that small grains require large amounts of potash and that need differs among varieties. For example, an average of 175 lb/A of K_2O was taken up from the soil by winter wheat varieties in a Virginia study which had an average yield of 124 bu/A. One variety took up 228 lb/A of K_2O. Stems and leaves contain most of the potash, while much smaller amounts are found in the grain.

When small grains are grown on soils testing low or medium in potash, profitable yield increases from added potash can be expected. Even small yield responses are profitable because potash is relatively inexpensive and the rates required are generally not large.

Winter wheat yields were increased on 12 responsive sites in Montana **(Table 1).** The first 20 lb/A of K_2O gave the biggest yield boost and produced extra bushels for only $0.55/bu. Another 20 lb of potash grew two more bushels at a cost of $1.10/bu.

Table 1. Potash increased winter wheat yields and produced extra bushels at low cost in Montana.

K_2O Rate	Winter Wheat Yield	Cost Per Added Bu
lb/A	bu/A	$/bu
0	38	—
20	42	0.55
40	44	1.10

Potash: $0.11/lb K_2O

Wheat growers in the eastern Midwest routinely apply potash because most of their soils test low or medium. On a low-testing soil in Ohio, potash increased winter wheat yields by 8 bu/A. The first 100 lb/A of K_2O grew extra wheat bushels at a cost of $1.83/bu **(Table 2).**

Table 2. Potash increased the yield of winter wheat grown on a low-K soil in Ohio.

K_2O Rate	Winter Wheat Yield	Cost Per Added Bu
lb/A	bu/A	$/bu
0	48	—
100	54	1.83
150	56	2.75

Potash: $0.11/lb K_2O

Adequate amounts of both potash and phosphate are needed for profitable yields of small grains. Spring wheat yielded best at the highest rates of K and P in a British Columbia study and the greatest yield response to both nutrients occurred at the highest application rate of the other nutrient **(Table 3).**

Table 3. Both K and P were needed for the highest yield of spring wheat in British Columbia.

P_2O_5 lb/A	K_2O, lb/A 0	60	120	Response to K
	Yield, bu/A			bu/A
0	37	43	43	6
115	39	52	55	16
230	41	55	58	17
Response to P, bu/A	4	12	15	

Extra bushels of barley can be grown inexpensively by applying adequate potash on responsive soils. On a low-K soil in Manitoba, potash grew extra bushels of barley for $0.55/bu and less **(Table 4).**

Dr. Wallingford is Eastcentral Director of the Potash & Phosphate Institute (PPI).

Table 4. Potash increased the yield of barley grown on very low K soils in Manitoba.

K_2O Rate lb/A	Barley Yield bu/A	Cost Per Added Bu
		$/bu
0	2	—
15	44	0.04
30	57	0.13
60	63	0.55
100	65	2.20

Potash: $0.11/lb K_2O.

Strong stems and lodging resistance require an adequate supply of potash. On soils testing high to very high, both the diameter and the breaking strength of winter wheat stems were increased by applied potash **(Table 5).**

Table 5. Potash increased the stem strength of winter wheat in Montana.

K_2O Rate	Diameter of Upper Stem	Relative Breaking Force of Upper Stem
lb/A	mm	
0	2.38	39
40	2.41	42
80	2.62	46

With the large amounts of K_2O required by the plant for high yields and improved lodging resistance, it's clear that profitable small grain production depends on maintaining an adequate potash supply available to the crop. ■

(Rotation systems. . . from page 9)

the rotation are the deciding factor. Soil type also must be considered in determining how often applications should be made, rates to be used, and levels to which soil test can be built. As a general rule, it takes 4 lb/A of K_2O to raise the soil test K level by one lb/A. But, as with P buildup, there is a wide range of soil test response to buildup applications. Local response data and recommendations are important.

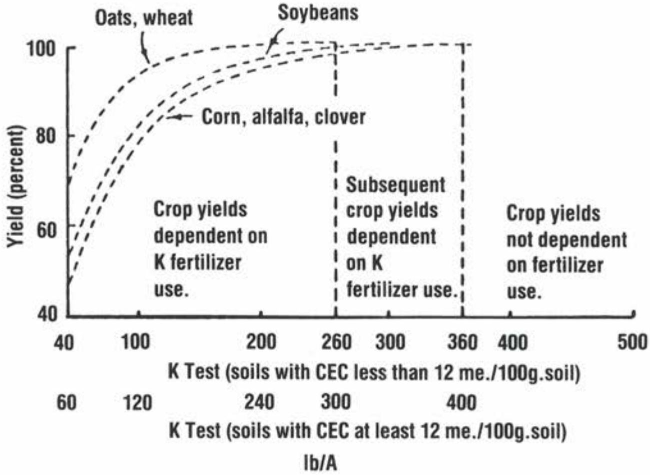

Figure 2. Relationship between expected yield and soil-test potassium (K). (University of Illinois response curve).

As with P, unless soil tests are excessively high, **maintenance applications** are required to keep K soil tests above the level required for optimum yields. In a crop rotation system, maintenance applications (and any needed buildup applications) should be made just ahead of the main primary tillage operation in the rotation. Once the soil tests have been built up to **adequate levels for all crops in the rotation,** it is not too critical when the maintenance application is made in the rotation.

Summary

When growing wheat as part of a rotation program, soil P levels should be built to higher levels than those maintained for corn-soybean rotations. For K, soil test levels adequate for optimum corn and soybean yields should be sufficient for optimum wheat yields as well.

Splitting N applications for wheat may offer some potential for improving efficiency. Late season N applications may be beneficial if growing conditions are especially favorable for high yields. Regular soil testing and maintenance fertilizer applications based on yields of all crops in the rotation will help ensure maximum profitability of the crop management system. ■

Tramlines – Roadways to Improved Small Grain Management

By D.E. Brann, M.M. Alley, and G.H. Hetzel

Tramlines are unseeded strips in small grain fields that match the wheel width of fertilizer and spray applicators, and the distance between tramlines equals the boom width of the applicators. These roadways improve timeliness and application accuracy of fertilizers, herbicides, crop protection chemicals and growth regulators.

TRAMLINES are best established at planting by blocking the seed metering openings that correspond to the tracks of the applicators that will be utilized during the growing season. The distance between tramlines should be at least 40 feet, so the land area left unplanted is not excessive. Tramline mechanisms that automatically block the planting of the appropriate rows are available on certain new drill models. A design for a mechanical tramline device for older drills is available from Virginia Tech.

The major advantages of tramlines include: (1) precise application of crop production inputs that must be made

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after planting; (2) less disease development because plants are not driven over and damaged (especially after jointing); and (3) partial yield compensation by the border plants along the unseeded strips. Tramlines make the decision to protect wheat yields from pests late in the growing season easier because the 5-10% crop loss due to wheel damage is not incurred, and again, applications are more precise.

Tramlines are a means to more efficiently conduct field operations after the wheat crop is growing. Readily available, inexpensive tramline systems, and the realization of benefits derived by full season small grain management, will result in tramlines in most small grain fields in the Southeast within the next ten years.

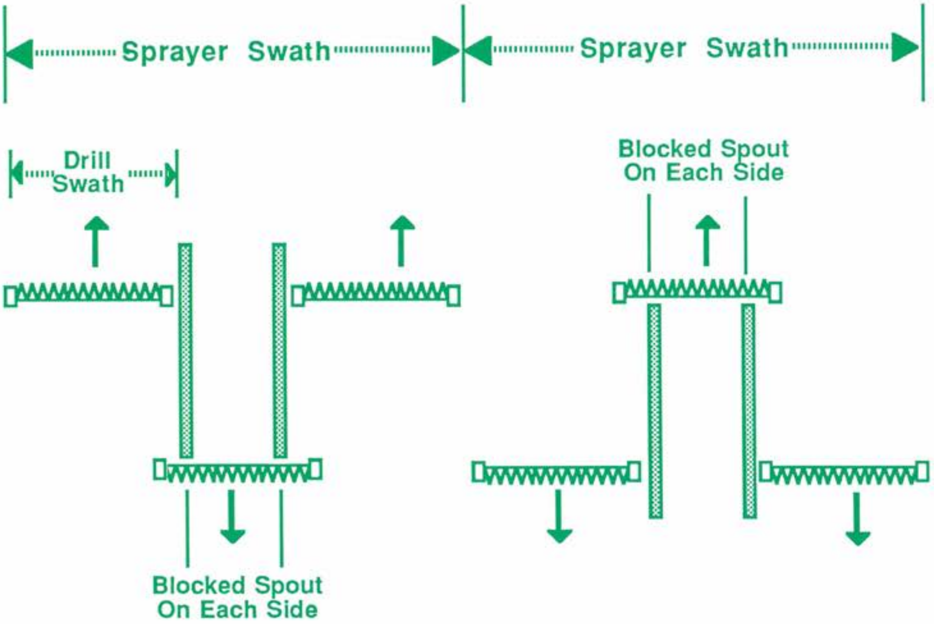
Tramline Considerations

1. Rows not planted (tram rows) must match sprayer and fertilizer application equipment in **both** track width and boom width.

   For example, the Virginia Tech tramline demonstration drill is setup to stop planting every third time it is raised so tramlines will be on 38-ft. centers (3 x 12 ft. 8 in.). This drill is also setup to establish tramlines with tracks on 63-inch centers.
2. The tramline system can be modified to tramline on any track width and any multiple of the drill width by changing the indexing wheel and/or the cam plate so it trams on 4 or 5 times the drill width.
3. Sprayer swaths should be as wide as possible. Sprayer capacity should be evaluated when the decision is made to establish tramlines.

Tramlines Formed at Wider Than Two Passes of the Drill

This system allows tramlines to be formed on selected passes of the drill by using a mechanism which blocks off the seed feed to the coulters immediately behind the wheels of the drilling tractor. Normal drilling can be undertaken until the pass at which the tramlines would be laid; then, the operator or an automatic mechanism activates the seed cut-off mechanism and thereby leaves the gaps required. ■



Managing Wheat by Objective Increases Profit Potential

By M.M. Alley and D.E. Brann

Higher wheat yields through intensive management can lower production costs per unit and increase profit potential. These higher yields don't just happen . . . they are achieved through a well-planned, carefully organized production management system.

WHEAT YIELD POTENTIAL in the 80 to 110 bu/A range is now possible in Virginia and other areas where management with clearly defined objectives is used. We are continually refining the system through our ongoing research programs and through demonstrations where research results are tested on field-size plots. Our management objectives can be divided into two parts . . . those which build yield potential and those which protect yield once the potential has been achieved.

Yield Building Objectives

1. Proper cultivar selection. Proper cultivar selection should be met several months prior to planting. Cultivars must be evaluated in terms of yield potentials, maturities, disease resistance characteristics, susceptibility to lodging, and quality for specific markets. Once all cultivar traits are known, it is possible to select the proper mix of cultivars for the individual farm. The entire farm should not be planted to a single variety because of the potential for a single disease or weather event, such as a late freeze, to reduce yields of the entire crop. Most varieties recommended today were not on the list 5 years ago and plant breeders continue their variety selection process.

2. Soil test for P, K and lime needs. Optimum crop nutrition is an important aspect of the intensive wheat production system. Soil test recommendations in Virginia provide the basis for adequate lime, phosphorus (P) and potassium (K) levels to meet the needs of an intensively managed crop. Adequate levels of P and nitrogen (N) are especially important to early root growth and plant development and are critical for meeting the stand establishment objectives. Thus, soil tests must be conducted on a schedule that permits efficient preplant or at-planting applications of fertilizer and lime.

3. Planting date. Plant as soon after the Hessian fly-free date as weather and conditions permit (about the time of first frost). Yields can be reduced severely some years when planting is delayed into the later fall periods.

4. Uniform stand establishment. Wheat yields can be increased dramatically in many instances simply by applying proper planting practices.

The specific objective for Virginia conditions is to establish a crop that will have 30 to 35 plants/sq. ft. that are well developed (1 to 2 tillers/plant by winter dormancy). High yields can be produced with lower plant populations under favorable environmental conditions, but growers must define those populations for their individual situations. To accomplish this objective, our research has shown that seeding rates should be determined in terms of seed-per-row-foot rather than by pounds or bushels per acre. Drills calibrated to provide 13, 20, 22, and 24 seeds per foot of row for 4, 6, 7, and 8-inch wide rows, respectively, will provide the proper seeding rate. Wheat seed size

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can vary greatly...as much as 50%. Calibrating drills to plant in terms of seed per foot of row so that each variety is planted at the proper rate can result in more uniform stands and higher field-average yields without significant additional cost.

Our work has shown that yields increase as row width is reduced—about 10% increase by going from 8 to 4-inch rows. While good wheat yields can be grown at the wider row widths, producers should consider narrow row drills when it is time to buy a new one.

Uniform emergence is a characteristic of high wheat yields. Land preparation and planting in the humid mid-Atlantic region must be adjusted to individual field requirements so that the seeds are placed at a depth of between 0.75 and 1.25 inches. Soil characteristics, tillage tools available, and possibilities for no-till must be considered. The uniform stand establishment objective can be accomplished with numerous combinations of equipment and conditions. Each grower must determine the appropriate tillage and planting system which best fits his conditions. Planning ahead of time for this essential objective is a must.

Soil characteristics, tillage tools available, and possibilities for no-till must be considered. The uniform stand establishment objective can be accomplished with numerous combinations of equipment and conditions, but planning ahead is essential for success.

5. A final stand of 60-70 heads/sq. ft. Final populations of 60 heads/sq. ft. with 30 kernels/head and a thousand grain weight of 35 grams/1,000 kernels (13,000 seeds/pound) are necessary for a yield of 100 bu/A. Stand establishment techniques and nitrogen management are important in determining final head number.

6. Nitrogen management. The winter wheat plant has only a small N requirement in the autumn because of its relatively small amount of growth prior to winter dormancy (20-25 lb/A N in Virginia). However, late winter-early spring nitrogen rate and timing are extremely important to efficiently build grain yields. Research in Virginia has shown that splitting N applications in the spring enables the grower to manipulate the wheat plant for higher yields and greater nitrogen efficiency.

During the tillering phase of wheat growth, the wheat plant will produce more tillers with increasing amounts of available N. In Virginia, the harvest population of 60 heads/sq. ft. requires at least 70 vigorous (three or more leaves) tillers/sq. ft. at the end of tillering (GS 30*). Crops that have low tiller numbers during late winter should receive 60 lb N/A at GS 25 in order to stimulate tiller development. Additional N is then applied at the beginning of stem elongation (GS 30-31) to meet the crop needs during the major N uptake period (jointing to flowering). In contrast, wheat stands with 80 or more tillers/sq. ft. during late winter will require only 40 lb N/A since tillering does not need to be stimulated. The majority of the N requirement for the crop with adequate tiller numbers will then be supplied at GS 30-31.

Recent Virginia research with soft red winter wheat has shown that tissue N content at GS 30 (immediately prior to jointing) can be related to the optimum N fertilization requirement for the remainder of the growing season. The use of tissue analysis to more precisely define the N fertilizer rate should be considered as part of an efficient wheat nutrient management system. Micronutrient and sulphur levels can also be evaluated in the tissue samples taken at GS 30.

Yield Protection Objectives

1. Establish tramlines. The use of these unseeded wheel-width strips is not essential for high yields, but they help assure more precise application of postemergence inputs and eliminate the concern of traveling over growing wheat. See page 12 of this issue for more complete story on this management tool.

2. Timely scouting program. The efficient producer will be monitoring his wheat throughout the growing season

*Zadok growth stage (GS) scale

with a timely scouting program. This scouting program is the basis for the decision-making process on when to apply yield protection chemicals. Threshold values have been determined for each of the following factors.

3. Weed control.

4. Insect control.

5. Disease control.

6. Lodging control.

Yield protection, as well as the yield building objectives, must be approached in a flexible manner since no two seasons or fields are exactly the same in terms of yield potentials and environmental conditions.

Summary

Clearly delineated yield building and yield protection objectives that are based on sound economics will enable growers to manage the wheat crop to their advantage. Managing wheat by objective enables growers to truly manage the crop, and not simply be spectators in their fields. Most importantly, management by objective increases profitability. ■

Correction for Winter 1986-87 issue . . .

THE Winter 1986-87 issue of *Better Crops With Plant Food* included an article titled "Potash Boosts Alfalfa Yields and Nutrient Uptake on Low Fertility Soil", by W.M. Walker, D.W. Graffis, and C.D. Faulkner. The article appeared on pages 20-21.

The nutrient removal numbers for five nutrients were incorrect as presented in **Table 1** of the article. Because of calculation procedure, the numbers as listed for boron (B), copper (Cu), iron (Fe), manganese (Mn), and zinc (Zn) were too high by a factor of 10, according to the authors.

A revised copy of the table appears below. Corrected numbers appear in shaded area.

Also, the next-to-last paragraph of the article, on page 21 of the issue, should be revised to read as follows:

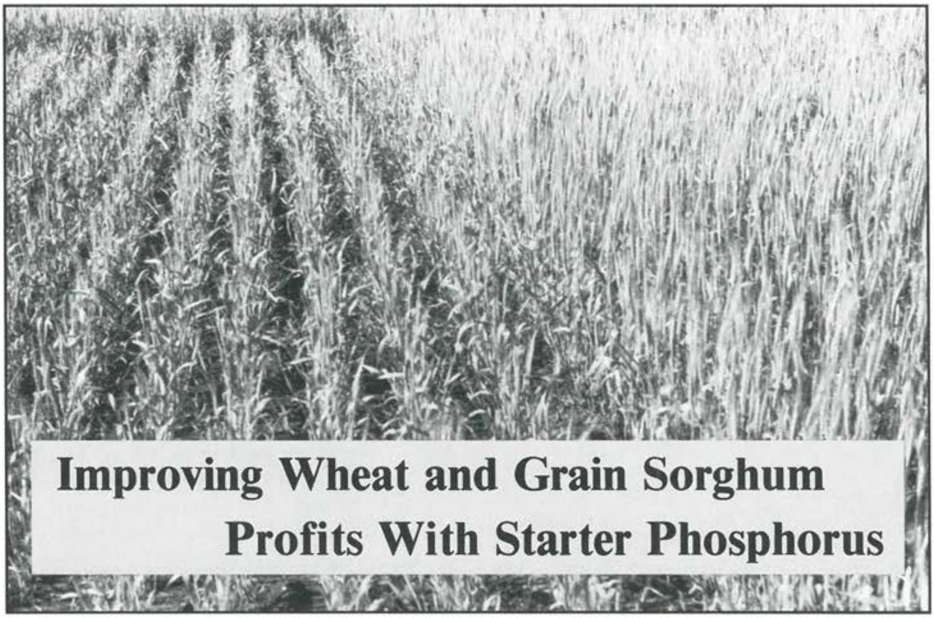
"Boron removal was significantly affected by B applications. It is evident that at a 4-4.5 ton/A dry matter yield almost 0.3 lb/A of B is being removed in the absence of application of B fertilizer; over 0.4 lb/A was removed on plots receiving B fertilizer."

The numbers and statements relating to potassium (K) are correct as presented in the article. ■

Table 1. Yield and nutrient removal by alfalfa as affected by potassium (K) and boron (B), Dixon Springs Research Center, 1985.

								lb/A							
	KF[1]	KS[2]	BF[1]	BS[2]	Yield	N	P	K	Ca	Mg	B	Cu	Fe	Mn	Zn
1	0	0	0	0	5008	166	18	78	81	16	.14	.05	1.5	.43	.09
2	100	0	0	0	6260	198	20	124	89	16	.20	.05	2.0	.54	.12
3	200	0	0	0	7810	238	23	192	105	16	.20	.06	2.0	.58	.15
4	300	0	0	0	8989	263	27	236	120	18	.23	.07	2.1	.62	.17
5	400	0	0	0	9033	263	24	262	104	15	.23	.06	1.8	.59	.16
6	500	0	0	0	8718	248	25	262	107	15	.19	.07	2.1	.60	.16
7	50	50	0	0	7903	234	25	177	109	18	.21	.06	2.0	.60	.16
8	100	100	0	0	9101	270	27	228	113	18	.24	.07	2.0	.59	.17
9	150	150	0	0	9376	273	27	259	112	16	.28	.06	2.0	.66	.19
10	200	200	0	0	9730	288	27	283	111	16	.24	.08	2.2	.67	.16
11	250	250	0	0	9455	266	27	295	107	14	.28	.08	2.0	.59	.17
12	500	0	3	0	9118	268	25	283	109	15	.40	.07	2.6	.63	.17
13	250	250	1.5	1.5	9134	261	25	297	112	14	.40	.06	1.9	.57	.18
14	500	0	6	0	8596	254	24	267	103	14	.42	.06	2.2	.60	.17
15	250	250	3	3	10099	281	29	322	118	16	.49	.07	2.1	.66	.20

[1]Fall applied after last harvest.
[2]Applied after first harvest.



Improving Wheat and Grain Sorghum Profits With Starter Phosphorus

By John L. Havlin, Ray E. Lamond and David A. Whitney

Regardless of source, starter application can improve phosphorus (P) use efficiency and profitability of many crops, including wheat and grain sorghum. Soil test P level influences response to starter and is an important tool in predicting where needs for starter are greatest. However, other conditions, such as cold and wet soils and soil compaction, can increase the need for starter P and the effects starter can have on yields and profitability.

STARTER PHOSPHORUS (P) applied with or near the seed at planting is a highly effective and efficient method of supplying the nutrient to crops. This is especially true for soils testing low in available P. In addition, when the crop price to P fertilizer cost ratio declines, P placement near the seed can help maintain profitability by optimizing P use efficiency. Recent research in Kansas evaluated starter P for both wheat and grain sorghum. The studies compared P rates, sources, application methods, and the effect of soil test level on starter P response.

Wheat

A study in eastern Kansas (conducted by David A. Whitney and Ray E. Lamond of the KSU Agronomy Department) compared starter P at 4, 8, 16, and 32 lb P_2O_5/A with broadcast P at 16, 32 and 64 lb P_2O_5/A on winter wheat grown on a very low P testing (2 ppm Bray-1 P) Pawnee clay loam soil. Two liquid fertilizers, an all-orthophosphate 9-18-9 and a polyphosphate 7-21-7, were used as starters and triple superphosphate was applied for the broadcast treatments. The two liquid P sources performed equally each year and only the average response of the two was compared to the broadcast applications.

The data in **Figures 1 and 2** are means of 3 years (1984-86). Starter P produced higher wheat yields than broadcast P **(Figure 1)** at equivalent P rates. Starter P produced nearly 25%

The authors are with the Department of Agronomy, Kansas State University (KSU).

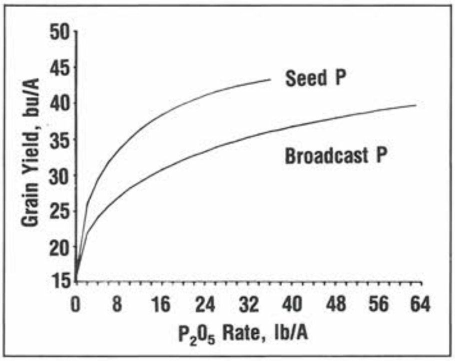


Figure 1. Wheat yields were dramatically affected by P rate and placement in this Kansas study.

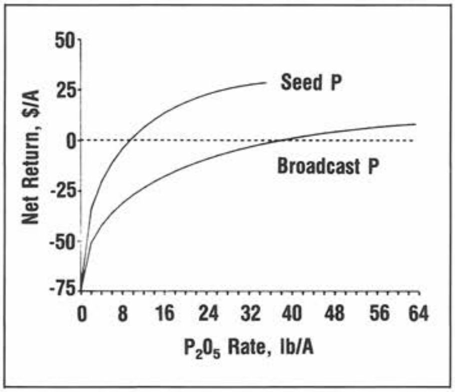


Figure 2. Use of starter P had big effects on wheat yields and net returns (supported wheat price, $4.10; $0.24/lb P_2O_5; $140/acre base production costs).

more yield than broadcast P at the 16 and 32 lb P_2O_5/A rates. Unfortunately, starter and broadcast P rates greater than 32 and 64 lb P_2O_5/A, respectively, were not included so the broadcast rate required to produce the maximum yield obtained with starter could not be directly determined. Regression equations developed from the data showed that the broadcast rate required for highest yield and net return was exactly twice the starter P rate (88 lb P_2O_5/A broadcast compared to 44 lb P_2O_5/A starter). Although caution must be used when extrapolating beyond the data, these results are similar to other comparisons of starter and broadcast P for wheat in the North Central region of the U.S.

Net returns **(Figure 2)** were calculated using a wheat price of $4.10/bu ($2.10/bu market price plus $2/bu deficiency payment), $0.24/lb P_2O_5 and $140 per acre base production costs. Yields with broadcast P did not show a net profit until rates reached nearly 40 lb P_2O_5/A compared to only 8 lb P_2O_5/A starter P. At 32 lb P_2O_5/A, the highest starter P rate, net return was $27.50/A compared to a loss of $3.10/A from broadcast P at the same rate.

Using the same equations calculated for projecting yields, maximum net return would have been $34.07/A with 44 lb/A P_2O_5 starter and only $10.15 with 88 lb P_2O_5/A broadcast. Although P rates in the study were not high enough for maximum yield, these data strongly support the positive influence of starter P on wheat production profits.

Grain Sorghum

Grain sorghum in the same series of studies also produced outstanding yield responses to starter P which had highly significant effects on profitability **(Table 1).** Soil test levels were low, 5 ppm Bray P_1 P. Note that while production costs per acre increased as P rates increased, production costs per bushel of grain declined and net returns increased over $40 per acre for both base yield situations. Yield level had a tremendous effect on overall profitability.

Comparisons of ortho and polyphosphate liquid P starters for three years indi-

Table 1. Starter P increased grain sorghum yields, lowered production costs per bushel and increased profitability.

P_2O_5 lb/A	Yield bu/A	Production costs $/A	Production costs $/bu	Net return 60 (bu/A base)	Net return 90 (bu/A base)
0	80	178	2.22	22	51
18	111	189	1.70	65	95
36	117	195	1.67	69	99

Grain sorghum, $1.74/bu loan price; $1.00/bu deficiency payment. P_2O_5 at $0.25/lb. Cost of harvesting, hauling extra grain, $0.22/bu. Soil test P, 5 ppm Bray P_1 (low).

cated equality of these materials in increasing sorghum yields **(Figure 3)** but no apparent advantage for either.

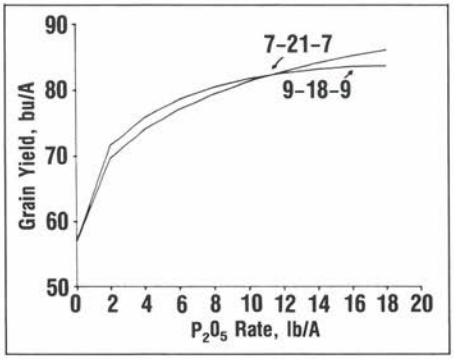


Figure 3. Grain sorghum responses to starter P are excellent but largely unaffected by P source.

An important question growers must consider is how to determine whether or not a profitable response to starter P may occur. The first tool available for identification of those soils is soil testing. A recent study in Kansas by Mark Hooker of the Garden City Experiment Station provided some excellent guidelines for grain sorghum production. Phosphorus soil tests ranging from 4 to 24 ppm Bray P_1 P were produced by 14 years of P applications at varying rates. Starter P applications of 20 lb P_2O_5/A were superimposed on those soil test P levels.

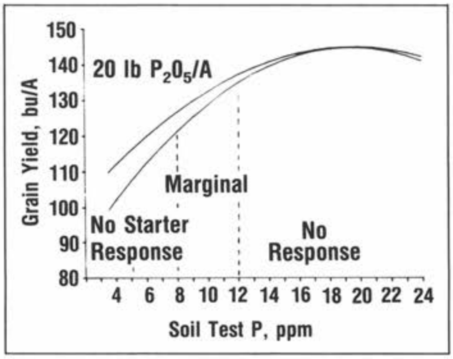


Figure 4. Irrigated grain sorghum responses to starter P were influenced by soil test P levels.

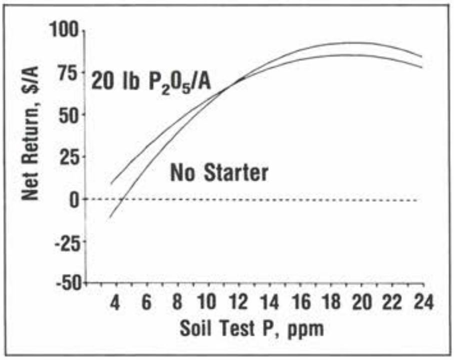


Figure 5. Irrigated grain sorghum net returns were increased by both starter P and soil test P levels. (Grain sorghum, $1.30/bu cash price plus $1.00/bu deficiency payment; $0.24 per lb P_2O_5; $240 per acre base production cost).

Two-year average yields of irrigated grain sorghum and effects of starter P on those yields are demonstrated in **Figure 4.** Averaged over both years, significant yield responses to starter P occurred at soil test levels below 8-12 ppm Bray P_1 P. Growth responses occurred between 12 and 16 ppm P, but the yield increases were only in the 2-3 bu/A range.

These data suggest that sorghum starter-P responses would be likely below 8 ppm P soil test P_1, and variable between 8 and 12 ppm P because positive responses were not observed at all soil test levels in that range each year. Net return **(Figure 5)** was lower for the starter P treatment beyond 12 ppm P because of the additional cost and the lack of starter P response.

Although 20 lb P_2O_5/A produced yield responses at low soil test levels, it is important to realize that this rate was not sufficient for maximum or optimum yield. Maximum yields occurred at 19 ppm soil test P **(Figure 4).** Even though a higher starter P rate may have produced larger yield responses, the data indicate the importance of soil testing as one criteria for predicting starter P needs.

Remember that other conditions such as earlier planting dates, reduced tillage, and compaction may enhance starter P responses. ■

Potassium and Chloride Effects on Wheat Yields and Profitability

By Paul Fixen

Yield responses by wheat to potassium chloride (KCl) fertilization appear to be much more common in some regions than potassium (K) soil tests would predict. Research has demonstrated that these responses are apparently due to K in some situations and to chloride (Cl) in others. Soil properties tending to be associated with K responses on high K soils are low temperatures, abnormally high density, and low soil water content. Chloride responses have generally occurred in high disease environments where soil Cl levels are low, although yield increases have not always been associated with disease suppression.

Wheat yield increases from KCl have averaged 5.4 bu/A across 15 responsive sites in South Dakota (42% of 36 total sites). Return per dollar invested at the responsive sites averaged more than $4 assuming no residual value for K or Cl. Approximately 50 to 100 lb/A of KCl was sufficient for near maximum yield in these studies. Potassium chloride fertilization is a potentially significant ingredient for maximizing wheat profitability even on high K soils. In the past decade, several new concepts have evolved that force us to reevaluate the role of KCl fertilization in the wheat belt of the U.S. and Canada.

POTASSIUM CHLORIDE (KCl) plays two distinct roles in wheat production systems. **The traditional role is as a source of K for soils where soil test K levels are insufficient based on classical calibration data.** In such a situation, it is highly probable that soil K will limit yield unless supplemental K is applied. Yield limitations are related to potassium's function in enzyme activation, stomatal control, sugar translocation and in promoting straw strength. Conventional fertilizer recommendations where soil K test level and yield goal influence rates recommended are based on this role of K.

The second role of potassium chloride is as a nutrient source where normally sufficient soil test K levels occur and conventional K recommendations are zero. A growing collection of data shows evidence of KCl response by small grains and other crops on high K testing soils.

Montana experiments on wheat have shown that 57% of 169 sites gave significant yield increases to K fertilizer **(Table 1).** North Dakota studies on barley conducted in the '60s resulted in yield increases or plump kernel increases 46% of the time. South Dakota studies on hard red spring wheat conducted over the last 5 years have demonstrated grain yield increases 42% of the time.

Table 1. K fertilization responses in the Northern Plains.

State	Sites	Yield increase frequency
Montana	169	Wheat - 57%
North Dakota	13	Barley - 46%
South Dakota	36	S. wheat - 42%

Montana data: Veeh and Skogley
North Dakota data: Zubriski et al.
South Dakota data: Fixen et al.

Dr. Fixen is Associate Professor, Department of Plant Science, South Dakota State University.

This article is adapted from a paper presented at the Second National Wheat Research Conference, National Association of Wheat Growers Foundation, Kansas City, Missouri; February 24-26, 1987

Table 2. Spring wheat study sites giving significant K response in South Dakota.

Treatment	Yield increase 84N	85S
	——bu/A——	
+KCl	6.3	4.7
+K	2.8	3.7
+Cl	4.6	3.1
Soil test K, lb/A	291	480

85S site disked 3 times to incorporate residue.

Table 3. Soil chloride levels affect Cl response by spring wheat in South Dakota.

Category	Soil Cl content	Yield responsive frequency	Average response at: Responsive sites only	Across all sites
	—lb/A-2-ft.—	%	—bu/A—	
Low	0-30	69	5.0	4.0
Medium	31-60	31	6.3	2.6
High	>60	0	—	0.3

Based on 36 locations from 1982-86.

An obvious question is: Why do these responses occur on soils that appear very well supplied with K? The responses must either be due to the K or due to the Cl in the KCl used in the studies. Evidence suggests that both elements may be involved.

Potassium Effects

Several factors influence the K supplying ability of soils other than the level of soil test (exchangeable plus water soluble) K present. Potassium must diffuse or move through waterfilms in the soil to contact root surfaces. Several studies have shown greater K response under dry conditions than when water is not limiting.

Other related factors that may affect K response are soil density and/or soil aeration. Several experiments on low to medium K test soils with reduced tillage corn have shown that K uptake is reduced in limited or no tillage systems. However, recent studies in South Dakota have shown reductions in corn plant K content in no-till systems even though soils test very high in K.

South Dakota wheat studies conducted over the past 5 years have produced only two responses to K out of 36 field locations **(Table 2).** One of these sites (84N) had the lowest K soil test in the group and some K response was expected. The other location (85S) tested 480 lb K/A and would not have received a K recommendation.

The response on the high K test site may have been due to soil compaction from three diskings prior to seeding. Studies and observations suggest that if the proper set of soil physical properties are in place, yields can be limited by K supply even though soil test K levels are high. The major soil properties involved appear to be low temperature, abnormally high soil density, and low water content.

Chloride Effects and Evidence of Response

With the exception of the one study mentioned earlier, South Dakota research over the past 5 years indicates that wheat responses to KCl on very high K soils have been due to chloride (Cl). In those studies, wheat yield response to KCl fertilization has been highly correlated with soil Cl content **(Table 3).** Experiments comparing KCl, $CaCl_2$, and KNO_3 and plant analyses **(Figure 1)** have confirmed that these responses are due to Cl and not to K.

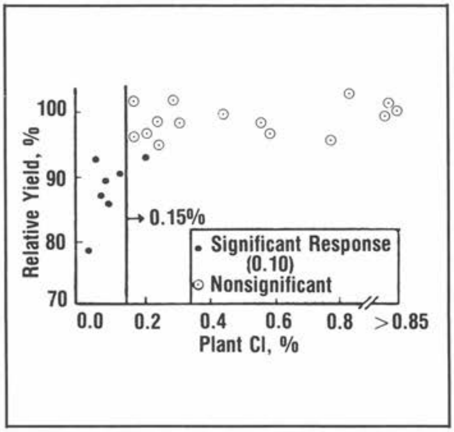


Figure 1. Relationship between plant Cl concentration and relative yield of spring wheat.

Several factors appear to be involved in Cl response by wheat in studies in the Northern and Central Plains and the Pacific Northwest. One of the most frequently reported effects of Cl fertilization is disease suppression. To date, at least 13 different foliar and root diseases on 10 different crops have been significantly reduced in severity in research conducted all over the world **(Table 4).** Researchers in Oregon and North Dakota who have concentrated their studies on root or crown diseases (Take-all and common root rot) feel that their yield increases are completely due to suppression of these diseases.

Oregon research reported by Christensen and Brett has developed a strong case for a specific chloride mechanism. They theorize that Cl acts as a nitrification inhibitor, increasing the amount of N taken up as ammonium (NH_4+) from the ammoniacal fertilizers used. This in turn causes plant roots to give off hydrogen ions and increases acidity at the root surface. The take-all fungus organism is inhibited by microorganisms favored by the more acidic rhizosphere pH. The Oregon studies have also shown that the effect is negligible if soil pH is above approximately 6.1.

Table 4. Diseases suppressed by chloride fertilization.

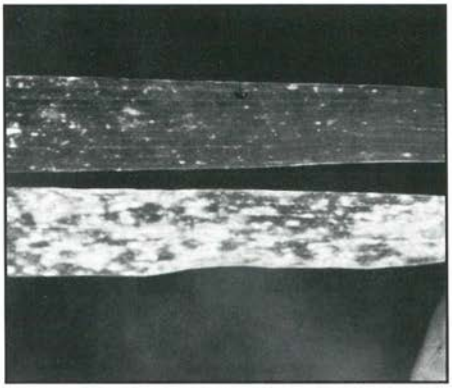
Location	Crop	Suppressed disease
Oregon	Winter wheat	Take-all
Germany	Winter wheat	Take-all
N. Dakota	Winter wheat	Tanspot
Kansas	Winter wheat	Tanspot
Kansas	Winter wheat	Leaf rust
Oregon	Winter wheat	Stripe rust
Gr. Britain	Winter wheat	Stripe rust
S. Dakota	Spring wheat	Leaf rust
S. Dakota	Spring wheat	Tanspot
S. Dakota	Spring wheat	Septoria
N. Dakota	Barley	Common root rot
N. Dakota	Barley	Spot blotch
Montana	Barley	Fusarium root rot
N. Dakota	Durum	Common root rot
New York	Corn	Stalk rot
India	Pearl millet	Downy mildew
Philippines	Coconut palm	Gray leafspot
Oregon	Potatoes	Hollow heart
Oregon	Potatoes	Brown center
California	Celery	Fusarium yellows

Chloride effects on common root rot in barley in North Dakota have been explained by Goos and associates as being due to a slightly different mechanism. The North Dakota researchers suggest that Cl fertilization decreases nitrate (NO_3^-) concentrations in the plant by either nitrification inhibition or general anion uptake competition between chloride and nitrate. They postulate that a plant having lower nitrate concentrations is less likely to develop a severe case of common root rot. Recently, North Dakota research has also shown that chloride fertilization can suppress the intensity of tan spot and other leaf diseases in winter wheat which also seems to be related to lowered concentrations of nitrate nitrogen in the plant.

South Dakota Cl responses by hard red spring wheat have not all been explainable by disease suppression. Common root rot and Take-all incidence have been very low and not related to yield increases. Dramatic suppression of leaf rust and reduction of tan spot by Cl fertilization has occurred in many studies **(see photo)** and has likely been responsible for large yield increases. Similar KCl fertilization effects in winter wheat were reported in 1986 by Kansas researchers on a high K soil when leaf disease pressure was very high. However, in the South Dakota research, yield increases have also occurred where disease suppression was not detected and in cases where fungicide was used to essentially eliminate foliar diseases. Therefore, it is possible that benefits, in addition to disease suppression, occur from Cl fertilization.

How Much KCl?

Potassium chloride rate decisions for wheat are best addressed by asking two questions: How much K? How much Cl? The answer to the first question starts with a K soil test and resulting recommendations based on local calibration data. However, even if the K soil test is high, the correct set of conditions may lead to a KCl need. Monitoring of plant K concentrations



VISUAL EFFECTS of KCl fertilization on suppression of leaf diseases in spring wheat. The leaf at the top of this picture received 120 lb of KCl per acre, that at the bottom none.

can be helpful. If whole wheat plants at early heading (Feekes growth scale 10.1) consistently test below 2.0-2.5% K, supplemental K should be considered for future crops. Generally, research in the Northern Plains has shown that 50 to 100 lb/A of KCl per acre will be adequate in such cases.

South Dakota research has shown that the rate of preplant Cl required for wheat depends on the quantity of Cl in the soil. Recommendations are currently calculated from the equation:

Fertilizer Cl in lb/A = 60 - soil Cl (lb/A-2-feet)

This may or may not be appropriate for other regions but it does provide a starting point based on research. In Oregon, for example, Jackson and co-workers have recommended Cl for Take-all control in winter wheat by a fall application of 35 lb/A of Cl with the seed or 80 lb/A of Cl if topdressed in early March. For ease of conversion to KCl, figure that KCl contains 45 to 47% Cl, 60 to 62% K_2O. Remember, if seed contact applications are planned, high rates of soluble salts in direct seed contact can cause germination problems, especially when soil moisture is short.

Profitability of KCl Fertilization

The bottom line for all inputs for improved crop management must be-evaluated. It is necessary to calculate-the return on every dollar spent from both short-term and long-term perspectives. Kansas data indicate positive KCl fertilization effects on returns from winter wheat. South Dakota data show that even with low wheat prices, return on the dollars invested in KCl is excellent **(Table 5)** assuming that it is possible to predict where KCl responses will occur. Soil testing for Cl is very helpful in making that prediction. Those returns **(Table 5)** do not account for any residual value of K or Cl which could be quite substantial. For example, in one study in eastern South Dakota, the residual yield effects in the second year were nearly as large as those immediately after application **(Table 6).**

Table 5. Profitability of KCl fertilization in South Dakota.

Average for	Wheat price $2.50	$3.50	$4.50
	$ returned per $ invested		
Responsive sites only	3.20	4.48	5.76
All 36 sites	1.24	1.73	2.23

KCl at $0.07/lb; 42% of 36 sites showed response significant at the 0.10 probability level.

Table 6. Residual effect of chloride fertilization in South Dakota.

Cl applied in 1985	Wheat yield 1985	1986	Response 1st year	2nd year	Total
lb/A	——bu/A——		——bu/A——		
0	58.8	48.3	—	—	—
27	62.6	49.9	3.8	1.6	5.4
54	62.8	51.4	4.0	3.1	7.1
109	63.2	52.1	4.4	3.8	8.2
218	64.2	52.2	5.5	3.9	9.4
436	64.1	54.3	5.3	6.0	11.3

Corn-wheat rotation

Potassium chloride is a potentially significant ingredient for maximizing the profitability of wheat production. There is little doubt of its value on low K soils or on the very high K soils of the Northern Great Plains. Researchers, dealers and growers in other areas where little data exist should be encouraged to evaluate these practices under their conditions. ■

Pacific Northwest

Cultural Practice Interactions with N Fertilization of Wheat

By Brad Brown

Improved crop varieties often require adjustments in management practices to achieve the goal of maximum economic yields (MEY). This article reports on interactions of nitrogen (N) fertilization and other factors with soft white winter wheat in the northwest U.S.

SOFT WHITE WINTER WHEAT (SWWW) grown with irrigation in the Pacific Northwest ranks among the highest yielding wheats in the world. Grain yields of 150 bu/A over more than 100 acres (farm averages) are not uncommon and yields in excess of 200 bu/A have been reported in some years.

There are several reasons for this excellent production. A favorable climate with relatively mild winters and cool springs reduces winterkill and promotes good tillering. The dryness of the climate reduces the severity of foliar diseases and limits insect problems. Plant breeders have developed and released stiff strawed varieties with high yield potential to take advantage of this high yielding environment. And, of course, adequate and timely water is ensured with irrigation.

Most of the irrigated wheat is rotated with other commodities. This reduces the severity of root diseases. Rotating winter cereals with other commodities has other advantages.

Sugar beets, potatoes, beans, onions, mint and other intensively managed crops generally are heavily fertilized. Consequently, residual phosphorus (P), potassium (K), and other nutrients are generally adequate for wheat grown after these crops. Even so, additional fertilizer may be added to the wheat to ensure maintenance of high soil test levels for succeeding crops. Though residual nitrogen (N) carryover can be sufficient to preclude the need for additional N on wheat, this is generally not the rule. Nitrogen deficiency is easily the most limiting factor for maximizing yield in the Pacific Northwest.

Despite some of the highest production in the world, irrigated wheat is generally the crop in the rotation that receives the least management. This is because wheat involves lower costs of production and lower potential returns than the other commodities. Lower costs include less insecticides, fungicides and herbicides.

To realize the potential yield of irrigated soft white winter wheat, both optimum environmental conditions and optimum management are necessary. Though plant breeders routinely identify the areas where their varieties are best adapted, the management factors necessary to realize the genetic potential of their varieties are not as frequently evaluated.

The release of Stephens, a SWWW from Oregon State University, represented a leap forward in the yield

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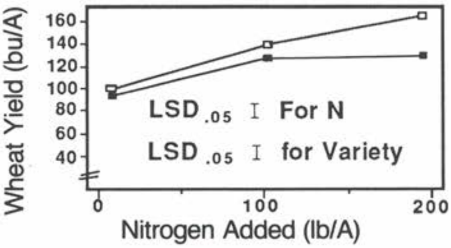

Figure 1. Grain yield response of Stephens (□) and Nugaines (■) SWWW varieties to nitrogen. Parma, 1978.

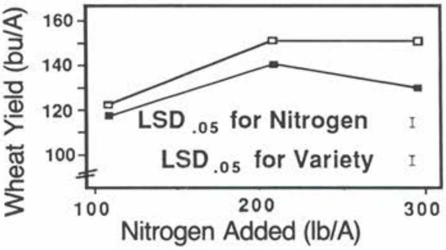

Figure 2. Grain yield response of Stephens (□) and Hill 81 (■) SWWW varieties to nitrogen. Parma, 1984.

potential of available varieties for the Pacific Northwest. However, our research has shown that this yield potential could not be realized unless higher N rates were used **(Figure 1).**

Varieties did not differ appreciably in yield with low or moderate N. Nugaines, the most popular variety in the Northwest for several years, did not increase in yield when N added exceeded 100 lb/A. In contrast, Stephens continued to increase in yield with the 200 lb/A N rate. The difference in yield when N was not limiting for either variety was approximately 30 bu/A. There was no lodging in these varieties and diseases were not a factor.

The increased N requirement of Stephens was information that was not released with the variety. Subsequent research and grower experience were necessary to learn just what management factors were necessary to realize the additional yield potential of this variety.

The variety Hill 81, a SWWW released after Stephens, is taller and has weaker straw. The increased potential for lodging was very evident in 1984. The yield of Hill 81 was seriously reduced due to lodging at the highest N rate. The yield of Stephens, in contrast, was not affected due to excellent straw strength and, therefore, the absence of lodging. See **Figure 2**.

Cultural practices other than variety selection have also been evaluated for their interaction with N fertilization. Planting dates have significantly affected the response to N. At moderate N rates, the earlier planting was the most productive. With excessive N, wheat yield of the earlier planting was reduced due to lodging, whereas for the later planting, there was no lodging and grain yield was not adversely affected. See **Figure 3.**

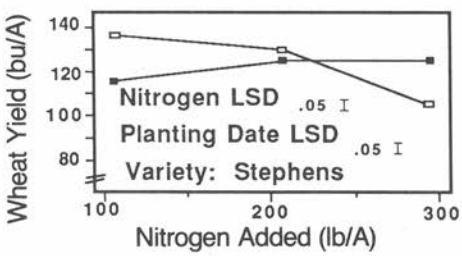

Figure 3. SWWW to N as affected by October 10 (□) and November 15 (■) planting dates. Parma, 1985.

Irrigated wheat in the Pacific Northwest can be extremely productive with good management. In striving toward maximum economic yields, however, there is a need for additional information regarding the specific management practices necessary to realize the genetic potential of improved varieties. In turn, there is also a need to understand how these factors relate to N, P and K fertilization. ■

Don't Overlook Micronutrients for Producing Most Efficient Yields (MEY) of Small Grains

By B. C. Darst

Micronutrients are essential to plant growth, and agronomic crops cannot grow without them. Deficiencies are not as common as for the major nutrients, but responses to fertilization can be dramatic when deficiencies do occur.

MICRONUTRIENT DEFICIENCY can limit yield just as dramatically as a major or secondary nutrient shortage. Data in **Table 1** illustrate the point with copper (Cu) on wheat.

Table 1. Copper increases wheat yield on an organic (peat) soil. (Minnesota)

Copper Rate[1]	Wheat Yield
lb/A	bu/A
0.0	2
1.5	41
6.0	42
12.0	48

[1]Applied as copper sulphate broadcast.

Only small amounts of micronutrients are required by small grains even at high yield levels. For some, especially boron (B), there is a narrow line between toxicity and deficiency. To avoid possible toxic effects, a crop's tolerance to a particular micronutrient must be known.

Micronutrient deficiencies occur less frequently than those of nitrogen (N), phosphorus (P), potassium (K), sulphur (S), and magnesium (Mg). Micronutrients most often deficient are Cu, Mn, and Zn while deficiencies of B, chlorine (Cl), iron (Fe), and molybdenum (Mo) occur less frequently.

Several factors, including high yields, influence the availability of micronutrients and the frequency of their deficiencies. Higher rainfall areas in the Corn Belt and the eastern U.S. are more conducive to micronutrient problems than are the dryland areas of the West, simply because of differences in yields.

Manganese deficiencies occur most often in high pH soils, particularly in states around the Great Lakes. Deficiencies have also been confirmed in the Prairie provinces of Canada. Manganese deficiencies have been identified on wheat on organic (peat) soils in certain areas of the Prairie provinces.

Copper deficiencies occur most often in wheat grown on peat and muck soils and have frequently been reported on organic soils in states around the Great Lakes. Responses have been confirmed in Minnesota, North Carolina, the Prairie provinces and the Eastern Canadian provinces. Deficiencies in Saskatchewan have been identified recently on high pH, sandy, gray soils.

Zinc and Fe deficiencies can occur on high pH, high limed and leveled soils. High soil pH can have a dramatic effect on Fe availability to wheat.

The entire subject of the effects of Cl for disease control and as a nutrient in small grain production is discussed in detail in Paul Fixen's article in this issue, beginning on page 20.

In summary, micronutrients are usually not the first limiting nutrient in small grain production. Soil availability of micronutrients should be monitored, particularly where higher yields are sought and in those areas where conditions favoring a deficiency occur. Micronutrients, like major elements, should not be allowed to limit small grain yields and profitability. ■

Dr. Darst is Vice President of Communications for the Potash & Phosphate Institute and Executive Director of the Foundation for Agronomic Research (FAR), Atlanta, Georgia.

Magnesium and Sulphur for MEY Small Grains

By Noble R. Usherwood

Intensive crop management practices and multiple cropping systems are boosting the need for magnesium (Mg) and sulphur (S) at a time when availability from the atmosphere and chemical NPK fertilizers are declining. Magnesium and sulphur should not become profit-limiting factors or restrict the full agronomic and economic expression of other inputs.

MAGNESIUM (Mg) and sulphur (S) are essential for small grain production and profitability.

For wheat, the challenge becomes one of balancing the **nutrient demand** by the "cropping system" with the **nutrient supply** provided by soil reserves, the environment, other production inputs, and the Mg and S fertilization program. The following factors bear directly upon the secondary nutrient status of MEY wheat production systems.

- **Higher yield of wheat** will remove larger amounts of Mg and S from the field **(Table 1).** The effect of such increased removal will grow as farmer yields climb from state averages toward university research yields.

Table 1. Nutrient uptake and differences in nutrient uptake in the above-ground portion of wheat in two wheat research trials in the Northwest.

Trial location	Yield	K_2O	S	Mg
		——lb/A——		
Idaho (irrigated)				
	164 bu/A	266	30	23
Washington (non-irrig.)				
Grain	108 bu/A	25	7	8
Straw	3.1 ton/A	80	3	5
Total Uptake*		144	10	13
Difference (lb/A)		122	20	10

*Maximum uptake values do not equal the totals of grain and straw because some loss occurs between milk stage and maturity.

- **Higher seeding rates** are recommended for MEY wheat production systems. The additional plants increase total nutrient uptake and boost plant to plant competition for available nutrients in the soil.
- **Higher N rates** promote vegetative growth and increase total uptake of magnesium. Sulphur requirements will also increase if a target N:S ratio is desired **(Table 2).** For wheat or forage crops to be pastured, special consideration will be required to ensure proper Mg nutrition for the livestock.

Table 2. Wheat responses to sulphur.

Sulphur lb/A	Yield bu/A	N:S Ratio Grain	N:S Ratio Plant	S Content (%) Grain	S Content (%) Plant	Soil S ppm 0-6"	Soil S ppm 6-24"
0	32	27:1	61:1	.08	.05	3.3	5.5
15	38	21:1	24:1	.10	.14	8.0	6.9

Kansas

- **Higher K rates** required for high yield MEY wheat systems can make it more difficult for plants to absorb Mg from low testing soils. By identifying and correcting such yield-limiting factors, a greater part of yield and profit potential can be realized.
- **Multiple cropping** is increasing due to economic necessity. The soil's nutrient reservoir filled to the monocrop level is now called

(continued on page 29)

Dr. Usherwood is Vice President Member Services and Southeast Director for the Potash & Phosphate Institute, 2801 Buford Hwy., NE, Atlanta, GA 30329.

Outstanding Graduate Students Receive PPI Fellowship Awards

FOUR graduate students have been selected as 1987 winners of Fellowship awards presented by the Potash & Phosphate Institute (PPI). Grants of $2,000 each are presented to the individuals, all candidates for either the Master of Science (M.S.) or the Doctor of Philosophy (Ph.D.) degree in soil fertility and related fields.

The 1987 winners were selected from nearly 50 applicants who sought the Fellowships. The four are:

- **Earl R. Allen,** Texas A&M University, College Station, Texas;
- **Duane T. Gardiner,** Oregon State University, Corvallis, Oregon;
- **John L. Kovar,** Purdue University, West Lafayette, Indiana;
- **Peter C. Scharf,** Virginia Polytechnic Institute & State University, Blacksburg, Virginia.

"It is a real privilege for us to recognize and encourage the achievements of these exceptional young scientists. They and their educational institutions can be justly proud of this recognition," noted Dr. R.E. Wagner, President of PPI and the Foundation for Agronomic Research (FAR). "The academic credentials and letters of recommendation submitted for each of the applicants speak highly for their qualifications."

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

Earl R. Allen is pursuing the M.S. degree in Soil Chemistry at Texas A&M University, and he plans to continue toward a Ph.D. His M.S. thesis project involves examining problems associated with surface-applied limestone for neutralizing soil acidity in Coastal bermudagrass pastures of East Texas. Mr. Allen graduated with High Honors from the University of Illinois in 1983. He then returned to the family farm at Delavan, Illinois, for two years before resuming graduate work. Currently, Dr. L.R. Hossner is chairman of his advisory committee at Texas A&M.

Duane T. Gardiner is working toward the Ph.D. degree in Soil Fertility and Plant Nutrition at Oregon State University. He previously earned B.S. and M.S. degrees at Utah State University, then worked as an Instructor of Agriculture at Dickinson State College (North Dakota) until 1986. Mr. Gardiner's Ph.D. research now is investigating phosphorus nutrition of pears grown on soils developed from volcanic materials in the Hood River Valley of Oregon. Dr. Neil W.Christensen serves as his major professor.

John L. Kovar is seeking the Ph.D. degree in Agronomy-Soil Fertility at Purdue University. He received a B.S.


Earl R. Allen


Duane T. Gardiner


John L. Kovar


Peter C. Scharf

degree at the University of Illinois in 1981, then worked in the fertilizer industry before earning the M.S. degree at Purdue in 1985. Mr. Kovar's M.S. research dealt with effective phosphorus placement for corn and determining its relation to soil properties. His Ph.D. efforts will concentrate more on differences in soil moisture and temperature, corn root growth and uptake of phosphorus and potassium from soil with a till-plant (conservation tillage) system. He is studying under the direction of Dr. Stanley A. Barber.

Peter C. Scharf is a candidate for the M.S. Degree in Agronomy at Virginia Tech. He graduated in 1983 from the University of Wisconsin honors program with highest distinction. Mr. Scharf's research efforts now relate to evaluation of nitrogen loss inhibitors for use with UAN solution applications to intensively-managed soft red winter wheat. The work is in the context of "maximum economic yield" systems and should lead to more efficient nitrogen fertilizer use. Dr. M.M. Alley serves as major advisor to Mr. Scharf at Virginia Tech.

The PPI Fellowship winners are selected by a committee of five members: two from the PPI staff and three from the PPI Advisory Council. Dr. J. Fielding Reed, President (Retired) of PPI, serves as Chairman of the Selection Committee.

"Again, the committee was impressed with the level of achievement these young people have demonstrated not only in academic pursuits but in other aspects of their lives as well, " Dr. Reed emphasized. ■

Magnesium and sulphur . . .
from page 27

upon to provide for two or more crops each year **(Table 3).** Some of the S and Mg will be tied up in previous crop residues, thus restricting these nutrients from becoming available to a rapidly developing second crop.

Table 3. Nutrient uptake by doublecrop wheat and soybeans.

Yield bu/A	N	P_2O_5	K_2O	Mg	S
	lb/A				
Wheat					
40	67	27	81	12	10
80	134	54	162	24	20
Soybeans					
40	(216)[1]	43	95	18	17
80	(324)[1]	64	142	27	25
Wheat (80 bu/A) plus soybeans (40 bu/A)					
	(350)[1]	97	257	42	37

[1]Legumes derive most of their nitrogen from the air.

- **Limestone requirements are under study.** When target pH levels are lowered, both Mg and S nutrition can be influenced. For Mg, this means less applied in the form of dolomitic limestone.
- **Residue management** can influence the Mg and S status. Marketing of straw removes additional nutrients. For high-yielding wheat, this means 3 tons of straw plus a total of 13 lb of Mg and 10 lb of S leaving the field.
- **Emphasis on the environment** will continue and result in greater need for including S in fertilization programs.

Growers know that improving wheat yield can be the best approach to lowering the unit cost of production. Many have already fine-tuned each of the major production practices. For some, Mg and S have now become the next most limiting factor. A shortage of either can cut crop yield and quality and, at the same time, lower use-efficiency of other inputs. Crop requirements for both magnesium and sulphur can be provided from the soil reserves and in the fertilization program for MEY wheat production systems. ■

New Publications Offered by ASA, CSSA, SSSA

THE American Society of Agronomy (ASA), Crop Science Society of America (CSSA), and Soil Science Society of America (SSSA) offer numerous publications of interest to individuals working in agronomy and related areas. Following are brief descriptions of three books now available. For more information, contact: ASA, CSSA, SSSA Headquarters
Office
Attn: Book Order Department
677 South Segoe Road
Madison, WI 53711

Fertilizer Technology and Use. Edited by O.P. Engelstad. Published by the Soil Science Society of America. Hardcover, 633 pages, 1985. ISBN 0-89118-779-0. Price $40.00 (members' first copy $32.00).

Fertilizer Technology and Use includes authorities' discussions on the field's developments within the last 10 to 15 years. Chapters from the second edition are updated and added to with new chapters on agronomic and statistical evaluation of fertilizer response and modern techniques of application.

Methods of Soil Analysis, Monograph No. 9. Edited by Arnold Klute (Part 1) and A.L. Page et al (Part 2). Published by the Soil Science Society of America and American Society of Agronomy. Part 1, *Physical and Mineralogical Methods*, second edition—hardcover, 1,216 pages, 1986. ISBN 0-89118-088-5. Part 2, *Chemical and Microbiological Properties*, second edition—hardcover, 1,184 pages, 1982. ISBN 0-89118-072-9. Price: Part 1, $60.00 (members' first copy $50.00); Part 2, $36.00 (members' first copy $30.00); Parts 1 & 2, $82.00 (members' first set $68.00).

One of our first important natural resources, soil, supports and provides nutrients to plants and animals which in turn helps us meet food and fiber needs. Soil also serves as a depository for waste materials—often correcting or masking many of our oversights. Since soil is a non-renewable resource, it is mandatory that we have the best possible understanding of the nature and properties of the various soils if we are to make the most efficient use of this valuable resource. *Methods of Soil Analysis, Parts 1 and 2, 2nd Edition,* presents the latest information available in this field.

Sulfur in Agriculture, M.A. Tabatabai, editor, Agronomy Monograph No. 27. Published by the American Society of Agronomy, Crop Science Society of America and Soil Science Society of America. Hardcover, 688 pages, 1986. ISBN 0-89118-089-3. Price: $52.00 (members' first copy $43.00).

Sulfur in Agriculture presents an authoritative summary of the current state of knowledge of sulfur and its availability for crop production as well as its role in animal nutrition.

The book covers many different aspects of sulfur in agriculture, including chemistry, biochemistry, and microbiology of the cycle; biochemistry in plants; plant and animal nutrition; stable isotope abundance variations in nature; forms and reactions of organic and inorganic compounds in soils, sulfur in the atmosphere, precipitation and irrigation waters and its effects on soils and plants; and sulfur deficiencies around the world. The monograph also focuses on plant response to sulfur in different regions of North America and the tropics; use of sulfur compounds as soil amendments; measurement of sulfur in soils, plants, atmosphere, and waters; availability indexes; fertilizer sources and economics of fertilizer use; and world reserves of sulfur. ■

Information Materials from PPI

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__**Managing Hard Red Winter and Hard Red Spring Wheat for MEY** Highlights fertilization and other important production practices for hard red wheat varieties or hybrids in North America. (26 slides)	______	$______
__**Managing Soft Red Winter Wheat for MEY** Discusses fertilization and other key production inputs for wheat in humid regions of North America. (23 slides)	______	$______
Cost for either set: $15 (MC* $10), with printed script		
MEY Analysis Software Package The **MEY ANALYSIS** package is an integrated set of Lotus 1-2-3 spreadsheets for an IBM or compatible personal computer system. The objective is to identify a system for achieving maximum economic yields (MEY). The software includes documentation and examples, making it "user friendly." **Cost: $180 (MC* $135)**	______	$______
An optional "Instructor's Guide" is also available and may be adapted for local workshops. **Cost: $60 (MC* $45)**	______	$______
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Plant Problem Insights for Maximum Economic Yields This is a colorful series of photo-cards, each with a concise discussion of a specific field problem, along with positive tips for increasing yields and profits. Indicate your choices: __Weak and Thinning Bermudagrass Stands-Potash Deficiency; __Alfalfa with Low Soil Fertility Suffers Dry Weather Stress; __Soil Compaction Limits Corn Growth; __Poor Early Wheat Growth (also available in Spanish translation); __Poor Early Corn Growth; __Lodged Corn; __Weak and Thinning Alfalfa Stands; __Soybean Cyst Nematode; __Mid-season Potassium Deficiency of Cotton; __Stunted Vine Growth and Poor Fruit Set of Grapes. **Cost: 10¢ each (MC* 5¢)**	______	$______

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Grower Education

*"It's great to get advice from an expert...
even when it's wrong."*

EVERY BUSINESS has the responsibility of providing its customers with information concerning its product.

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It is certainly proper to point out the good features of the product—to show how it can increase pleasure, health, happiness, profits.

False claims are to be avoided. If problems can result from improper use, this information should be available also.

The fertilizer industry is not among the best in providing its customers with good information. Over the years, study after study has shown that:

1. The grower is eager for **more** information on the proper use of fertilizers.
2. The dealer is the source most consulted by the grower.

Better educational programs are essential if both producer and dealer are to provide growers with sound answers. New and valuable agronomic information is constantly being developed. **"Agronomics"** is a dynamic field. But the educational team is shrinking.

What are we in the college, in the industry, and on the front lines doing to both keep abreast of the latest and to provide the grower with what he needs to know?

NOT ENOUGH.

—*J. Fielding Reed*

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