SF-1013

Fertilizer Management Strategies For Spring Wheat Production In Northern Climates

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Approaches to fertilization management have been rather stable for a number of years. It appears the 1988 drought has made a number of spring wheat producers wonder if their soil tests for nitrate-nitrogen can be right (Figures 1 and 2). The lack of much moisture recharge during the fall of 1988 and higher than usual N levels may prompt spring wheat producers to apply little if any nitrogen (N) fertilizer to their 1989 crop. This might be called low input production. There are fertilizer management strategies for these and other conditions.

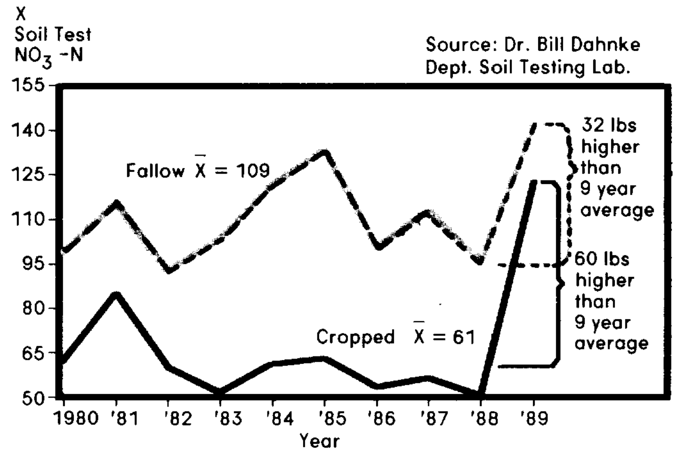

Figure 1. Nitrate nitrogen averages for September.

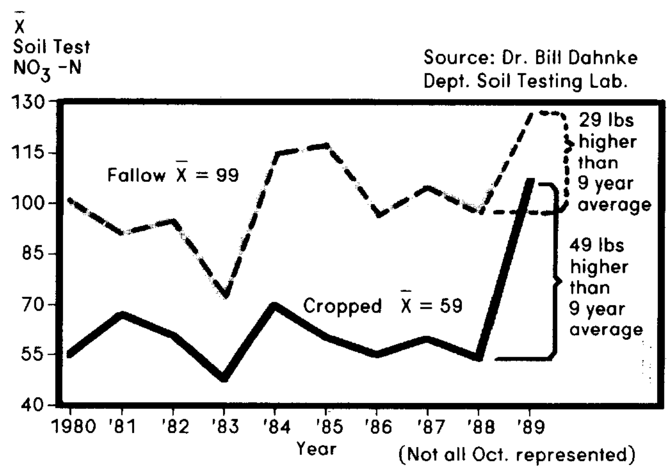

Figure 2. Nitrate nitrogen averages for October.

Conventional Approach

The following is reproduced from the 1988 Crop Production Guide and represents a conventional or quite traditional approach to soil fertility management. South Dakota and Montana also utilize similar philosophies.

Soil Testing and Soil Fertility Management

by William C. Dahnke

Many people are of the opinion that the soils of North Dakota are very fertile. Yet if North Dakota growers did not apply approximately 250,000 tons of fertilizer nitrogen each year, wheat production would decrease from 350 million bushels annually to about 150 million bushels. If phosphorus and potassium were not applied, additional yield decreases would occur. Soil fertility management consists of knowing what nutrients to apply, how much to apply, how and when to apply them. Soil testing is a practical tool that can simplify soil fertility management. In addition to soil testing, methods of fertilizer application and other management decisions will be discussed.

Soil Fertility Management Philosophies

The first step in management of soil fertility is looking at the options available. Following are some of the advan-

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tages and disadvantages of commonly held soil fertility management philosophies:

1. Apply 50 pounds per acre of 18-46-0--This is a practice used by many small grain producers. In a small grain-summer fallow rotation this may be a good practice some years. However, with continuous cropping yields would often be limited by nitrogen.
2. Maintenance fertilization--This philosophy promotes the idea that the amount of N, P, K and other nutrients removed from the field by the crop should be replaced each year. A deficiency of a nutrient is not likely to occur using this idea. The disadvantage of this practice is that the amount of nutrient in the soil is not considered. Therefore, too much of some nutrients and not enough of others may be added, resulting in an investment that does not pay a dividend.
3. Deficiency correction--With this approach the soil is tested and the needed nutrients are applied to eliminate soil fertility as a limiting factor in reaching a certain yield goal. Only the nutrients lacking in the soil are recommended. This is the philosophy used by the NDSU Soil Testing Laboratory.
4. Soil fertility build-up--The idea here is to increase available nutrients to a high enough level so that there is no possibility of a nutrient deficiency. Crops well supplied with nutrients will do better under unfavorable weather conditions and they are also able to take full advantage of ideal weather. While the economics of this practice may be questionable, producers who have built up the available nutrient supply consistently get good yields. The disadvantages of this philosophy are high cost and possible environmental pollution.

Soil Testing and Soil Fertility Management

Soil testing should be treated as the best available **guide** to the fertility status of your fields. Soil testing should not be considered an exact science for the following reasons:

1. Soil samping--Soil is not uniform. Each field will usually have many soil types. In addition, the distribution of nutrients is variable due to natural factors and past management. Our recommendation is to take 20 subsamples from each field. Research data indicate the soil test value obtained from 20 subsamples will be within 20 percent of the average 80 percent of the time. If you take only five subsamples per field, you would be within 50 percent of the average less than half of the time. In other words, you could probably do as well by guessing. The point here is that you need to take good soil samples to get good soil test results. For more information on soil sampling see Soil Science Research Report 8, Sampling for Soil Testing. It is available from North Dakota county agents and the NDSU Bulletin Room.
2. Soil test calibration (or what do the numbers mean?)--Most soil test laboratories report soil test results as numbers and then as a category, such as very low, low, medium, or high. Following is what each of these categories mean at NDSU.
   a. A **very low** soil test means that if the nutrient is applied the **chances are very good** that a yield increase will occur.
   b. A soil that tests **low** has a good chance of responding to added nutrients. Responses in this category will be very dependent on weather conditions.
   c. Fields testing in the **medium** category will occasionally respond to additions of the nutrients.
   d. **High** testing fields are unlikely to respond to additions of fertilizer.

Soil test results can be understood only when the name of the test is also known. For instance, in Minnesota the Bray No. 1 test is used for phosphorus while in North Dakota the Olsen test is used (the Olsen test is used because the majority of our soils are high in lime).

The meaning of soil test results is also dependent on the nutrient. In the case of **nitrate-nitrogen** which is completely soluble in water, the results represent the **number of pounds per acre of nitrogen that are available to the crop.** The nitrate-nitrogen results are reported by the NDSU Soil Testing Lab have the same availability as the common nitrogen fertilizers. Sulfate-sulfur soil test results are similar.

The results for **all the other nutrients** (phosphorus, potassium, zinc, iron, copper and manganese) **are index values (Table 1) that give an indication of the relative supply of the nutrient.**

As an example, a phosphorus soil test result of eight does not mean there are only 8 pounds of P per acre. It means that the reserve supply of phosphorus in the soil is so low that during periods of rapid crop growth the roots will be removing phosphorus from the soil solution at a rate faster than the slightly soluble phosphorus compounds can go into solution. The result will be a phosphorus deficient plant and a lower yield. At a phosphorus soil test of 30, however, the reserve supply of available phosphorus is large enough so that even during periods of very rapid plant growth phosphorus will be dissolving in the soil solution at a rate fast enough to supply crop requirements.

The difficulty in sampling a material as variable as soil and the great influence that weather conditions have on crop growth from year to year reduce the ability of soil testing to accurately predict crop response to applied

Table 1. Soil test calibration levels for North Dakota

Nutrient	Name of test	Categories			
		very low	low	medium	high
Phosphorus (P), lb/a	Olsen	0-9	10-19	20-29	30+
Potassium (K), lb/a	NCR-13	0-99	100-199	200-299	300+
Zinc (Zn)*, ppm	DTPA	0-0.5	0.6-1.0	1.1-1.5	1.6+
Iron (Fe)*, ppm	DTPA	—	0-2	3-5	6+
Copper (Cu)**, ppm	DTPA	—	0-0.2	—	0.3+
Manganese (Mn)**, ppm	DTPA	—	0-1	—	2+
Sulfur, lb/a-2'	500 ppm PO_4	0-15	16-30	31-45	46+
Chloride, lb/a-2'	—	0-19	20-39	40-59	60+

* This calibration only for sensitive crops such as corn, potatoes, flax, and beans.
** Deficiencies of these nutrients have not been confirmed in North Dakota. Interpretation is only a suggestion.

nutrients in the **medium** category. However, you can be certain that when a field is in the **very low** category, added nutrients are needed to get high yields. You can also be certain the fields in the **high** category do not need additions of fertilizer. Knowing these two facts give such an advantage to soil testing over the next best alternative guide to crop fertilization that there is no comparison.

Fertilizer Application Methods and Soil Fertility Management

Once it has been determined that fertilizer need be applied, the next question is how should it be applied. In many cases the method of application will be dictated by the source of the nutrient, but in other cases factors such as soil test, crop, rate, nutrient, etc. will determine the method of application.

In dryland agriculture there are two basic methods of fertilizer placement with many small variations. One is to put the fertilizer in a band and the other is to broadcast it evenly over the soil surface.

Fertilizer is usually broadcast when a large amount is needed to build up the level of a nutrient in the soil, the nutrient is soluble in the soil or as a conventient way to apply annual needs. Broadcast nitrogen fertilizer, especially 45-0-0 (urea), should be worked into the soil shortly after application. Broadcast phosphorus and potassium should be worked into the soil before planting the crop or they will not be in a position for the plant to use them.

There are numerous variations of banded fertilizer placement such as: pop-up, drill row, 2 x 2, blind row, knifed, deep band, etc. Banded fertilizer is generally considered more efficient in the year of application on low testing soils. On most soils testing **medium or above** the method of application is not as important except when using no-tillage or minimum tillage. When little tillage is used deep banding of fertilizer is needed to prevent a large buildup of nutrients near the soil surface.

Very favorable results have been obtained with deep banding (6-8 inches deep) of N and P. This has been especially true on fields testing low in nitrogen and phosphorus. Do not expect large increases in yield as a result of deep banding on non-responsive (medium and high testing) fields. When all things are considered, deep banding of fertilizer is probably the best method of fertilizer application.

Some producers are interested in building up the level of nutrients in the soil. This can be done with all nutrients but is not recommended for nitrogen. Nitrogen can be lost by leaching and as a gas. Therefore, **nitrogen needs should be determined and satisfied each year.** In the case of phosphorus it takes about 10 pounds of P_2O_5 to raise the soil test level one unit. The top 6 inches of soil in a field testing eight in phosphorus can be increased to 20 by the application of about 120 pounds of P_2O_5 per acre over and above the annual removal by the harvested crop (40 bushels of wheat would remove about 25 pounds of P_2O_5). About 5 pounds of K_2O needs to be added to increase the potassium soil test by one unit. The amount of fertilizer needed to raise the soil test level of the other nutrients has not been studied.

Fertility Management in Summary

Many factors determine what nutrients need be applied, how much to apply, when to apply them, and how to apply them. Soil testing is the best guide available to help answer most questions concerning soil fertility management. A brief summary of the most important points in soil fertility management follows:

1. Soil sampling--Accurate soil sampling is crucial. A poor sample is more useless than guessing. Take at least 20 subsamples per field for reliable test results.
2. Soil testing--Soil testing is the very best **guide** available to determine the nutrient status of each of your fields. If a nutrient is rated as **very low** by soil test there is little doubt that a response will occur if the nutrient is added. When a nutrient is rated **high** by soil test there is very little chance that a response will occur to added fertilizer. Nutrients rated as medium are in a questionable area as far as crop response is concerned. In the low area it is advisable to add enough phosphorus and potassium to at least replace what will be taken off by the crop. Have your soil tested in a laboratory that uses soil test calibration data obtained on North Dakota soils.
3. Nitrogen--Sample the top 2 feet of soil and have it tested for nitrogen each year. Available nitrogen levels fluctuate greatly from year to year in an unpredictable way. Losses from fall applied nitrogen on medium and fine textured soils in North Dakota are usually very small. Nitrate forms of nitrogen should not be applied to sandy soils in the fall because of possible leaching loss. If you are low on operating capital and your fields test low in available nitrogen, it would be poor management to cut expenses by not applying nitrogen.
4. Phosphorus--Soil test phosphorus levels are very stable. Testing for phosphorus once every five years is usually adequate. Phosphorus does not move in the soil, so it should be applied before a deep tillage operation or at a depth in the soil where it will be available to the roots (usually 4 to 8 inches deep). It is possible to build soil phosphorus levels by applying 10 pounds of P_2O_5 per acre in the top 6 inches for each unit increase in the phosphorus soil test. It is also possible to apply enough phosphorus in one year to last a two or three-year rotation. With a three-year rotation phosphorus would be applied to one-third of the fields each year. When cash renting land that **tests very low** in phosphorus, expenses can be cut by banding one-half to one-third of the broadcast recommendation. When you are farming land testing medium or above in phosphorus and you are low on operating capital, it would be possible to cut back on phosphorus fertilization.
5. Potassium--Potassium soil fertility can be managed much like phosphorus. Over 90 percent of the fields in North Dakota are high in available potassium.

Tables which summarize the NDSU Soil Testing Lab recommendations for nitrogen, phosphate and potash use on crops grown in North Dakota are available in circular SF-882, "North Dakota Fertilizer Recommended Tables and Equations Based on Soil Test Levels and Yields Goals." Table 2 presents the charges presently in effect at the NDSU Soil Science Department Soil Testing Laboratory.

Table 2. Soil Testing Chargès at NDSU

Tests	Depth	Cost
Nitrate-Nitrogen	0-24"	$2.50
	0-6" & 6-24"	3.00
	2-3'	1.50
	3-4'	1.50
Phosphorus, Potassium & pH	0-6"	4.00
Soluble Salts	per depth	1.00
Zinc, Iron, Manganese & Copper	0-6"	8.00
Zinc	0-6"	3.00
Iron	0-6"	3.00
Manganese	0-6"	3.00
Copper	0'6"	3.00
Organic Matter	0-6"	3.00
Sulfur	0-6" & 6-24"	6.00
Sulfur	0-24"	3.00
Chloride	0-6" & 6-24"	6.00
Chloride	0-24"	3.00

Moderately Intensive Approach

The following summary statement from Minnsota Extension Service publication AG-FO-2900 reflects the concern that small grain production be profitable.

Steps for Maximum Economic Small Grain Production

1. Test soil to determine fertility of field.
2. Fertilize based on soil test and yield goal of 15 percent to 20 percent above your average yield for past five years.
3. Select a variety with good yield potential and with disease resistance.
4. Plant only good quality, disease free seed of a known variety.
5. Plant spring grains early and winter grains at optimum date.
6. Plant in 6- to 7-inch rows with a grain drill with press wheels.
7. Plant on basis of seeds per unit area rather than pounds per acre; 15 seeds per linear foot of 6-inch row.
8. Check fields early and carefully for weeds and use proper control measures.
9. Check fields carefully for insects and control if necessary.
10. Use fungicides only if leaf diseases have been a problem and potential exists for a problem.
11. Provide adequate, safe storage and frequently inspect grain in storage.
12. Develop a marketing strategy.

Low Input - Sustainable Concept

This is a fairly new terminology for a system of farming. University of Nebraska researchers summarize their approach to sustainable fertility management as "Fertilize the Crop, Not the Soil." The following statements are listed:

- Precision calibrated soil test and "accurate" fertilizer recommendations.
- Band application of fertilizers.
- Planting time and sidedress application of nitrogen (N) for maximum efficiency.
- Use of available manures and wastes.
- Allowing N credit for legumes and for nitrate in irrigation water.

The following is a reproduction of five "Mistakes to Avoid" listed in the publication, "Switching to a Sustainable System" by Frederick Kirschemann. (Copies available at no charge from Northern Plains Sustainable Agriculture Society, RR1 Box 73, Windsor, ND 58424.)

Mistakes To Avoid

In every system of farming there are some practices that should be avoided in all circumstances. In attempting to convert to a sustainable system there are at least five such abstentions. To attempt any one of the five items listed below is to assure failure.

1. Don't move too fast. Changes in the soil take time. Give the soil time to regenerate itself.
2. Don't just stop using chemicals. A sustainable system has more to do with what you put into place than it does with what you stop doing. To just stop using chemicals without putting a regenerative system into plant is a guaranteed prescription for disaster.
3. Don't go cold turkey. Try out sustainable strategies on a small scale, monitor the results, make adjustments, then try it again on a larger scale. A big mistake on a small acreage turns out to be a small mistake. A small mistake on a large acreage turns out to be a big mistake.
4. Don't continue monocropping. Monocropping can only be maintained through large infusions of fertilizers and pesticides. In order for a sustainable system to work it needs the diversity of a good crop rotation system.
5. Don't start with more acres than you can afford to risk. Changing systems always involves some risks. Switching to a sustainable system is no exception. No matter how successful your neighbor's sustainable system may be, yours might need to be different. Every farm is unique. Every farmer is unique. The grower and the land need to discover each other and together they need to find the ways to care for each other and sustain each other. It is part of the joy and the challenge of sustainable farming.

The sustainable system can be modified to suit your own needs. The use of a legume in the rotation seems to be key item. The same concept is presented in a somewhat different manner in "Rotations for Profit," NDSU Extension Bulletin 48.

Intensive Management Concept

Maximum Economic Yield (MEY)

This management approach is based on the idea that producers can learn more about what makes their wheat plant run. Part of this is visiting their fields to observe spring wheat plants at critical development stages.

Fertility Management Considerations for MEWY (Maximum Economic Wheat Yield)

Most of the research that makes MEWY a possible model for spring wheat production has been performed at the USDA-ARS Northern Great Plains Soil-Water Research Lab at Mandan, North Dakota.

The management of nitrogen fertilization for MEWY requires an understanding of some other influencing factors. These are, especially, growing degree days (GDD) and development (growth) stages of spring wheat (Figure 3). The producer looking to improve yields while utilizing the same or less inputs also needs to have some understanding of PAW (plant available water). Water is the fuel that runs the spring wheat plant's engine. He must also remember that other management inputs (weed, insect, disease control) must be in place.

More information about use of GDD to tract development stages of spring wheat and PAW can be obtained from your local county extension office. Ask for NDSU Extension Bulletin 37 and Software Users Guide 1. You may want to obtain more information on PAW from Montana. They have an excellent section on it in their new ICPM Record Keeping System. The system sells for $20.00. Their Montguide MT8325 also covers the subject very well.

The amount of PAW used by the wheat plant can be compared to the gas (fuel) used to run the engine in your car or tractor. Water is the gas the wheat plant's engine runs on. The plant nutrient most often limiting in the Northern Great Plains that determines how well the wheat plant uses water is nitrogen (N), especially on recrop land.

We can generalize and say wheat yield is largely determined by PAW and availability of adequate N, if other good management is in place and growing season temperatures are not excessive. Then:

yield = ASSM + EGSR + AN

where ASSM = available stored soil moisture

EGSR = effective growing season rainfall

AN = adequate nitrogen

We can estimate the amounts of ASSM and AN so perhaps we can use risk management to arrive at a level of EGSR the producer is comfortable with based on his experience on his farm. Figure 4 shows the type of relationship we can utilize in our determination of N management strategies.

If growing season temperatures run high (over 90 degrees during critical developmental stages), all management strategies go down the drain (Figure 5).

Nitrogen (N) Management Strategies

Keep in mind that adequate levels of N can more than double wheat yields (Table 3), which may lead to doubling the WUE (water use efficiency) of your wheat crop (Table 4). Relate the WUE to the MPG of your car or pickup. Everyone has some idea of the miles per gallon (MPG) their vehicle gets. The following data may help you get a better idea of the WUE of wheat and how your management can improve.

Refer to Table 5 and Figure 6 to see some of the historical data and very recent data on effect of PAW on spring wheat yield.

Nitrogen is often the most limiting plant nutrient for spring wheat production in the Northern Great Plains. It runs a close second to water. Nitrogen is essential for high yields and high quality grain. Deficient plants are light green or

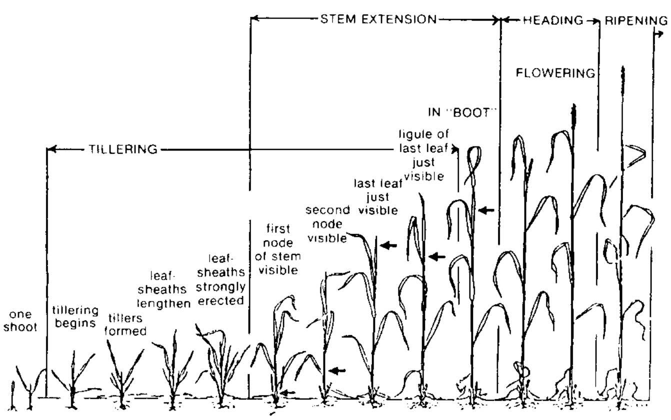

Figure 3. Stages of plant growth and development. (Patterned after Feekes (Large, 1954))

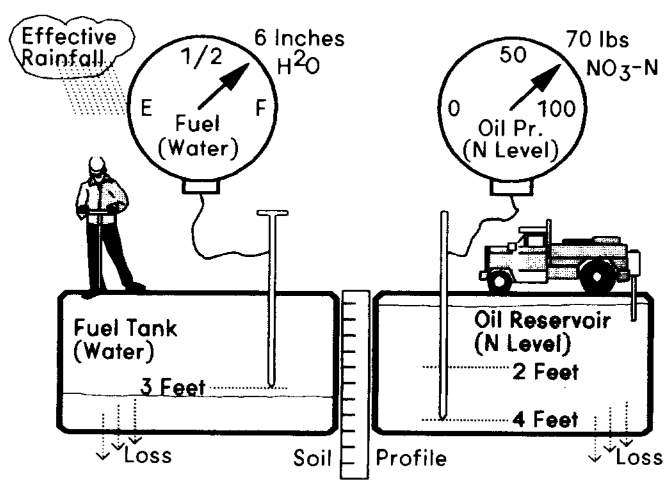

Figure 4. N management strategies.

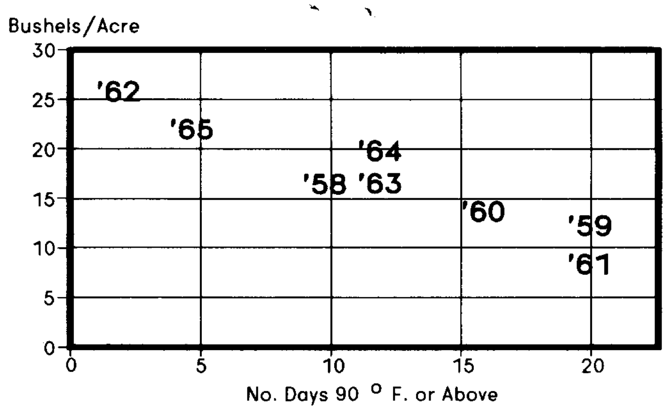

Figure 5. Effect of 90° F days on spring wheat yields 1958-1965.

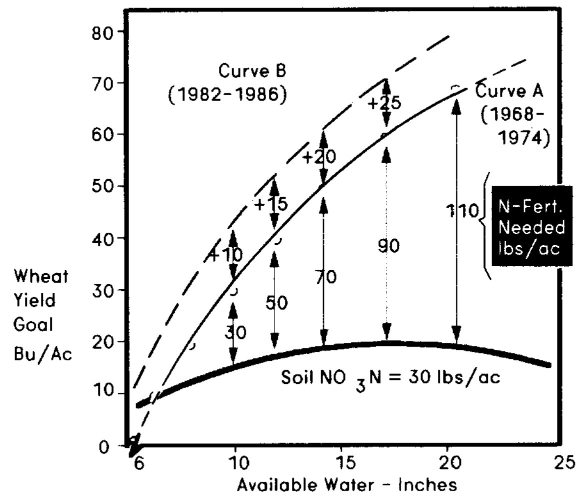

Figure 6. Available water as related to wheat yields and nitrogen needed for dryland recropping. (Black and Bauer)

Table 3. Response of Colt wheat to N levels at high water level. (Bauer, Unpublished Data)

N Level	Yield
lbs NO_3-N to 4 ft	Bu/A
50	17.3
90	29.8
140	46.0
215	59.2

Table 4. Spring wheat response to fertilizer placement and available water*.

Treatment	Water use efficiency bu/inch water	Yield bu/acre
Check	3.0	19.8
Fertilizer broadcast	4.0	28.6
Fertilizer deep-banded	6.1	43.5

* Saskatchewan

yellowish and growth is stunted. The lower leaves will show deficiency symtoms first. Affected leaves turn yellow, wither and eventually die. Nitrogen management for intensive spring wheat production is designed to eliminate the lack of N being a limitation for yield or protein levels.

Guidelines For Nitrogen (N) Management For Intensive Spring Wheat Production

1. For intensive management production, determine N needs by multiplying the yield goal by 3 pounds N, instead of the 2.5 pounds used on conventional management. Example: 70 bu. x 3 lbs. = 210 lbs. N required.

Table 5. Effect of moisture supply on wheat yields in North Dakota under inadequate and adequate soil fertility levels during 1957-1964.

Moisture supply*		Unfertilized Yield			Fertilized Yield		
Range	Avg.	Range	Avg.		Range	Avg.	
------ inches ------		- pounds per acre -		Bu/A	- pounds per acre -		Bu/A
5.6- 7.3	6.4	618-1,254	936	15.6	822-1,926	1,272	21.2
7.9- 8.8	8.4	246-1,608	1,050	17.5	366-1,956	1,290	21.5
9.0- 9.9	9.5	858-2,100	1,242	20.7	1,140-3,018	1,776	29.6
10.1-10.9	10.5	588-2,346	1,356	22.6	1,020-2,802	1,776	29.6
11.3-12.5	12.0	600-2,352	1,518	25.3	894-2,946	2,106	35.1
12.6-13.5	12.9	414-2,106	1,602	26.7	792-2,856	2,136	35.6
13.7-14.8	14.1	732-2,814	1,728	28.8	954-3,402	2,340	39.0
15.0-16.2	15.8	690-3,006	1,782	29.7	1,188-3,276	2,346	39.1
16.5-17.8	17.1	498,2,340	1,590	26.5	1,668-3,282	2,202	36.7
18.7-22.9	20.1	1,158-2,922	1,746	29.1	1,902-3,510	2,448	40.8

* Sum of growing season precipitation and stored available soil water at seeding to 4 feet or to a zone of dry soil occurring within the 4-foot depth.

Source: Crops and Soils Magazine, April-May, 1967. Work of Bauer, Young and Norum.

2. Soil test to 4 feet. Subtract the soil test N value from the total N needed, as determined in step 1. This remaining amount is the amount of nitrogen needed in addition to what is already in the soil. Example: If soil test results showed 70 pounds of N available, then 210 pounds - 70 pounds = 140 pounds N still need to be provided.
3. Take 70 percent of this amount (.70 x 140 pounds = 98 pounds) and plan to apply this N at or before seeding.
4. The remaining 30 percent of the N (.30 x 140 pounds = 42 pounds) goes on as foliar treatment in three to four applications at the 2-2½ leaf stage (Haun 2-2.5), at late tillering to early jointing (Haun 5-6), and at the boot stage (Haun 9).
5. One other N application for protein enhancement could be applied at Haun growth stage 11 if it appears protein premiums are going to be good and potential yield level is high.

The 70 percent to 30 percent soil/foliar split of N application can be varied depending on moisture conditions, relative cost of available N materials and equipment available to apply N pre- and post-plant. Suggestions are for central North Dakota 60 percent to 40 percent, and 50 percent to 50 percent in western North Dakota.

The enhanced protein in durum will be shown as fewer yellow berries and a greater percentage of hard vitreous kernels, which means a better grade.

Only the producer can make the decision about delaying N to post application. The cost of post-applied N will be higher than N from 82-0-0.

These guidelines are based on N content data shown in Figure 7 and also take into account the concern many have about N use and a clean environment.

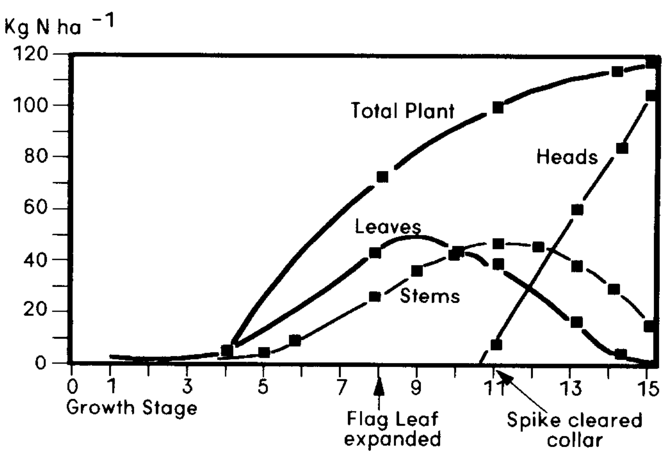

Figure 7. Nitrogen (N) content of Alex-Olaf in the total plant, in leaves, stems and heads from emergence to maturity 1981-1982. (Bauer)

Phosphorus (P) Management

Phosphorus is the second most limiting element in spring wheat nutrition in much of the Northern Great Plains. Without adequate P, early plant growth is slowed, tillering is reduced, head numbers and size are diminished and maturity is delayed. Phosphorus deficient plants will be stunted and may show a light, gray-green color in early growth. Wheat takes up about 65 percent of its P before boot stage, so it is important to have P available early (Figure 8). Depending on the type of wheat and variety or hybrid, 0.4-0.5 pounds P_2O_5 will be removed in each bushel of grain. Some recommendations call for annual applications of 0.75 pounds P_2O_5 per bushel of grain produced to maintain high soil test P levels.

MEY wheat management requires large amounts of available P. Soil testing is essential to establish levels of available P and to determine amounts to apply for correction of deficiencies. Experience in intensive wheat management (IWM) suggests that high P soil tests are more conducive to high yields. A P management practice suggested for IWM/MEY is a heavy initial P broadcast application to build P levels followed by drill row or deep banding of P to maintain soil test levels. Heavy initial P applications have been shown to have long residual effects on P soil tests, yields and profitability. About 10 pounds of fertilizer P_2O_5 is required to increase the soil test level one unit on calcareous (limey) soils such as are cropped in North Dakota.

Recent studies with spring wheat in Montana and South Dakota indicate that about 25-27 parts per million (ppm) bicarbonate-extractable P (Figure 9) in the surface 6 inches of soil is required to obtain 100 percent of yield potential in a spring wheat-fallow system and about 20-22 ppm on recrop land. These values are considerably higher than the 16 ppm bicarbonate-extractable P that most soil testing labs consider adequate for routine wheat production goals.

Phosphorus application methods can affect P availability and use efficiency. In soils with low levels of available P, band applications of P fertilizer pre-plant or placed with

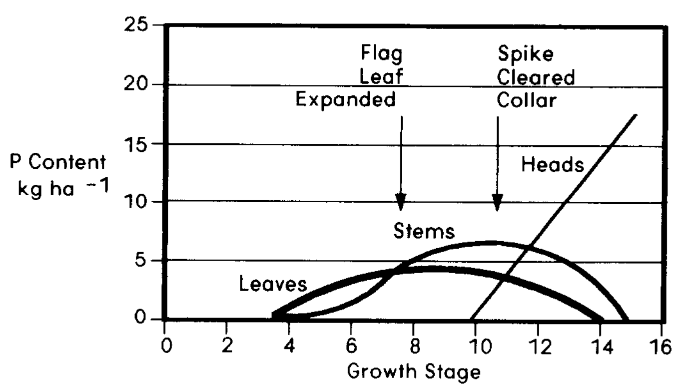

Figure 8. Phosphorus content in leaves, stems, heads, of Alex-Olaf spring wheat in relation to growth stage, 1981-1982. (Bauer)

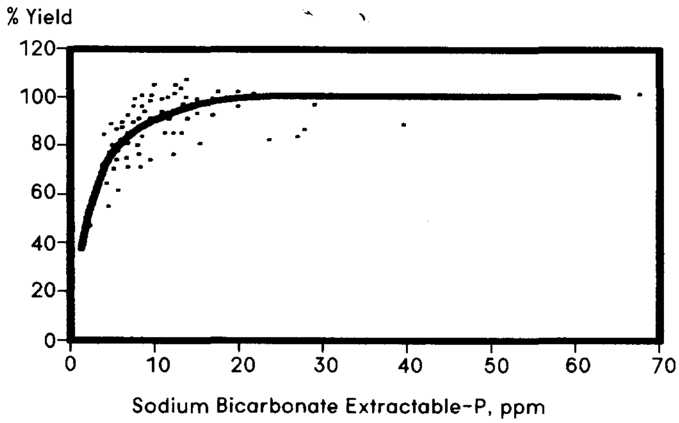

Figure 9. Relative yield potential as a function of soil test P level in an annual cropping system. (Halvorson)

or near the seed are generally more efficient in the year of application than broadcast applications at modest rates of application. On soils testing medium to high in available P, the difference in effectiveness between broadcast and band applications of any type is lessened. At the lower soil test P levels, recommendations usually call for 1.5 to 3 times more broadcast P than if P is to be banded. Improved yield, vigor, and stand establishment have been demonstrated with starter P, even at high levels of soil test P. Cold soil conditions associated with spring wheat production accentuate that starter effect.

SUGGESTED EDUCATIONAL MATERIALS: Contact Dr. Ed Vasey, Box 5575, Fargo, ND 58105-5575 or call 1-800-342-4538.

1. The Montana Small Grain Guide, Bulletin 864, Cooperative Extension Service, Agricultural Experiement Station, Montana State University, Bozeman, Montana.
2. How Cereal Crops Grow, EB3, NDSU Extension Service. Revised edition in press.
3. Fertilizer Management for Today's Tillage Systems, Potash Phosphate Institute.
4. Estimating Small Grain Yield Potential From Stored Soil Water and Rainfall Probabilities, Montguide 8325, Cooperative Extension Service, Montana State University, Bozeman, Montana.
5. **Slide-Tape Package:** Maximum Economic Yields (MEY) and the Environment, Contact Dr. Ed Vasey at 701-237-8883.
6. **Videos:** Available from NDSU Extension Communication. See your county agent.
   - Hi-Tech Nitrogen Management
   - Implementing Maximum Economic Yield Systems
   - MEY...A Focus on Cents
   - Breaking the Yield Barrier
   - A Concept You Can Bank On
   - Fertilizer Economics
   - Fertilizer Placement
   - Maximum Economic Yield
   - Soil Basics
   - Soil Testing: Where the Yields Begin
   - Use of Soil Testing in High Yield Agriculture
   - Maximum Economic Weed Control
   - Foliar Fertilization Management for MEY
   - Dissecting the Wheatspike for Projecting Potential Yield
   - Keys to MEY Management for Spring Wheat
   - MEY in Action
   - Digging For Top Crop Profits

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