Winter Wheat Fertilization in the Northeast Intermountain Region of Oregon

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F. V. Pumphrey and P. E. Rasmussen[1]

SUMMARY

1. Most dryland wheat needs 40 to 100 pounds of nitrogen per acre. Irrigated wheat needs 75 to more than 200 pounds of nitrogen per acre. Fields which have grown mainly forage legumes may not need nitrogen fertilization.

2. Early spring application of nitrogen fertilizer is more effective in increasing the yield of winter wheat than preplant application. Approximately one-half as much nitrogen needs to be applied in the spring compared to preplant application.

3. Dryland wheat should be fertilized as early as possible in the spring. Irrigated wheat with little growth should be fertilized when spring growth starts; stands that have large to excessive growth should be fertilized 2 to 4 weeks after spring growth has started.

4. Most wheat fields need to be fertilized with sulfur if they are fertilized with nitrogen. Apply 15 to 30 pounds of sulfur per acre at the same time the nitrogen fertilizer is applied.

5. Most soils in northeast Oregon are able to supply enough phosphorus for maximum yields of winter wheat. For soils needing phosphorus fertilizer, apply 30 to 60 pounds of phosphate (P_2O_5) before seeding and work into the soil. Approximately half as much phosphate needs to be applied if it is drilled with the seed.

6. Potassium and trace element fertilizers applied to winter wheat have not given a significant yield increase.

INTRODUCTION

Application of commercial fertilizer is one of many technological improvements that wheat producers have adopted during the last several decades. Other practices such as timely use of modern machinery, weed control with herbicides, and improved varieties have contributed to continuously increasing productivity. Skillful coordination of these controllable factors plus favorable weather (mainly amount and timeliness of rainfall) or irrigating have been producing wheat yields only dreamed about a few years ago.

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[1]Agronomist, Columbia Basin Agricultural Research Center, Oregon State University, Pendleton and soil scientist, USDA-ARS, Pendleton, respectively. The authors wish to thank Extension agents in Baker, Union, and Wallowa Counties and Extension specialists for their cooperation in this work.

These higher yields require larger quantities of nutrients from the soil. Fortunately, most soils are supplying adequate amounts of nutrients for plant growth except nitrogen and sulfur. A few areas are deficient in phosphorus.

Crops, yields produced, and fertilizer practices in the rotation influence the response expected from fertilizing wheat. The residual value of phosphorus and sulfur applied to a legume may be enough to meet the needs of one or more wheat crops. The nitrogen fixed by a good stand of alfalfa or clover can reduce and possibly eliminate the need for nitrogen fertilizer on one or more crops to follow. Large quantities of organic matter low in nitrogen, such as straw, require additional nitrogen fertilizer to meet the simultaneous nitrogen demands of decomposing residue and the growing crop.

Wheat yields range from less than 30 to more than 130 bushels per acre. This large range reflects the effect which variations in rainfall, management, and soil have on yield. The higher yields result from favorable growing conditions and excellent management. Most but not all of the low yields are associated with low rainfall and/or poor rainfall distribution. Some low yields with no response from fertilizing are the result of diseases or poor management such as an inadequate control of perennial weeds, i.e., quackgrass and Canada thistle.

Numerous field experiments and laboratory analysis have been completed. The objective of this work has been to increase the effectiveness of fertilizers through greater knowledge of factors affecting wheat growth. The objective of some of the laboratory work has been to evaluate the reliability of soil and plant tissue tests which will aid making decisions on how much fertilizer to use. Results of field and laboratory work are summarized in this report.

NITROGEN

Rate of Application

The suggested rate of application of nitrogen for optimum yield varies from none to more than 200 pounds per acre. This wide range results mainly from the amount of moisture available to the growing crop. Water is definitely the most influential factor affecting yield and determining how much fertilizer to apply. Both quantity and time of rainfall are important under dryland conditions. Soil depth and water holding capacity of the soil also influence the amount of water available to plants. Time of fertilizer application also influences the rate of application which will produce the optimum yield.

Average yield increases of 12 and 17 bushels per acre in dryland winter wheat can be expected, respectively, from 40 and 80 pounds per acre of early spring applied nitrogen when no serious moisture stress occurs (Figure 1). Little or no yield increase has been observed in fields suffering from some adversity, such as too many weeds, poor stand, diseases, and shallow soil or when grown following a forage legume such as alfalfa.

Nitrogen fertilization, especially overfertilization, stimulates vegetative growth. The larger growth requires more water and increases the risk of late season drought. Examples of the adverse effects of overstimulating early growth in dryland wheat and inducing late season drought are presented in Figure 1 and Table 1. Wheat fertilized with 40 pounds of nitrogen produced 6 bushels per acre more grain than non-fertilized wheat. Wheat fertilized with 120 pounds of nitrogen produced 2 bushels less than non-fertilized wheat. Test weight of the wheat with no applied fertilizer was 59 pounds per bushel but decreased to 55 pounds when 120 pounds of nitrogen per acre was applied. Protein content of the grain was undesirably high (over 12%) in the wheat fertilized with 80 or 120 pounds of nitrogen per acre. The same problem of overstimulation of early growth causing reduced yield and test weight occurs in irrigated fields which are allowed to develop moisture stress during the later stages of growth.

Table 1. Nitrogen fertilizer effect on grain yield, test weight, and protein where moisture stress occurred in later stages of growth

Nitrogen[1]	Grain	Test weight	Protein
lbs/acre	bu/acre	lbs/bu	%
0	34	59	8.5
40	40	58	11.7
80	39	56	12.7
120	32	55	15.7

[1]Nitrogen fertilizer broadcast when growth was starting in early spring.

Large yield responses to nitrogen fertilizer are obtained in most irrigated wheat fields which have not been used primarily for the production of forage legumes (Figure 2). The optimum rate of application varies from 75 to more than 200 pounds of nitrogen. The lower rates are suggested for wheat which has less than optimum growing conditions; an example is wheat which does not have adequate water from the late boot stage of growth to maturity. Wheat rotated with other well fertilized non-cereals or peas needs 100 to 150 pounds of nitrogen per acre applied in the spring. The maximum need for nitrogen occurs in those fields receiving the best management and where wheat follows wheat; 200 or more pounds of nitrogen in split application are suggested.

Figure 1. Dryland winter wheat response to early spring applied nitrogen for normal and deficient rainfall

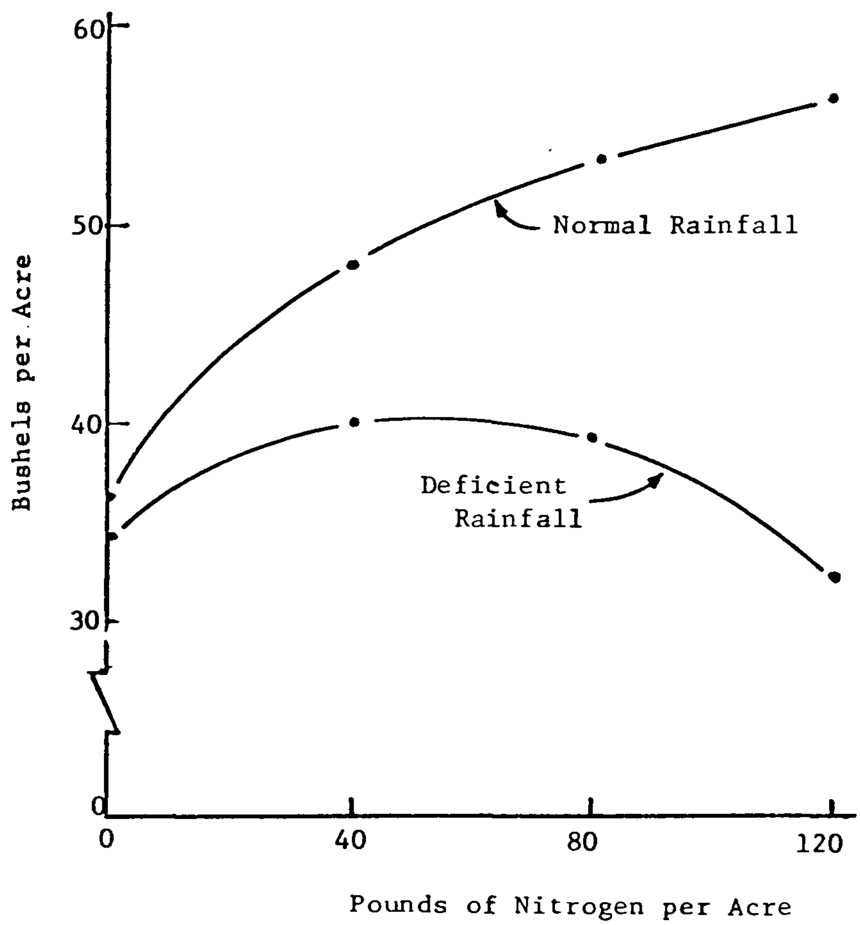
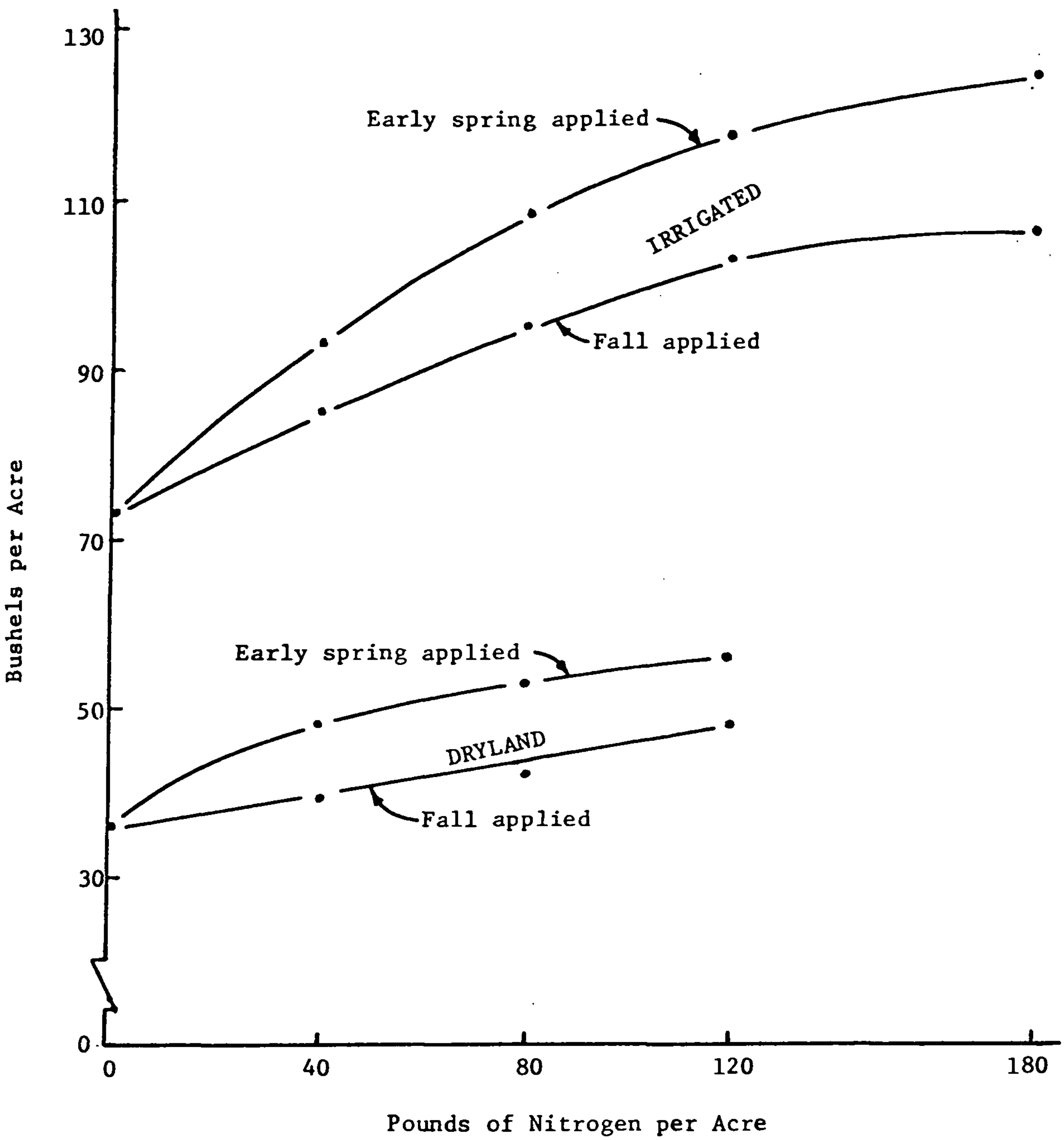


Figure 2. Dryland and irrigated winter wheat response to fall and early spring nitrogen fertilizer application



Some irrigated fields in northeast Oregon are used primarily to produce forage legumes. These fields usually remain in forage production for many years and are managed by ranchers whose main enterprise is livestock. Cattle may be fed on these fields during the winter. These fields when cropped to cereals produce good yields for several years without nitrogen fertilizer. This is in contrast to the grass seed fields in the Grande Ronde Valley. The grass seed fields, although heavily fertilized with nitrogen, need to be fertilized with nitrogen when cropped to winter wheat.

Nitrogen fertilizers have not had good residual value. Usually much less than 25 percent of the wheat's nitrogen requirement has been obtained from nitrogen applied to a previous crop. Thus, for efficient fertilizer use, each crop should be fertilized with enough nitrogen to fulfill the need of the crop not supplied by the soil.

Time of Application

Preplant application is nearly as effective in increasing grain yield as is early spring application under low rainfall conditions. As the amount of spring rainfall or irrigation water increases to the growing crop, the value of an early spring application increases compared to preplant application (Figure 2). With decreasing water deficit, the effectiveness of spring application of nitrogen increases to the extent that approximately one-half as much nitrogen need be applied in the spring compared to a preplant application. Where soils are waterlogged over winter, even greater efficiency of early spring over preplant application is obtained. Wheat plants which have started spring growth are able to immediately utilize the applied nitrogen, allowing less time for losses to leaching, denitrification, and tie-up by decomposing organic matter.

Dryland wheat should be fertilized as early in the spring as is possible to insure the maximum possibility of rainfall after application. Irrigated wheat with modest or little growth should be fertilized as spring growth is starting. Where plant growth is large to excessive, spring nitrogen application should be delayed until two or four weeks after spring growth has started. Delaying fertilization until after spring growth has started reduces plant height, straw growth, and the hazards of lodging without decreasing grain yield.

Wheat fertilized with the nitrogen split into a fall and a spring application has seldom produced more yield than wheat fertilized with all the nitrogen applied in early spring. Most soils have sufficient nitrate nitrogen to supply the needs of the seedling growth in the fall. Fall growth in most fields is between 100 and 600 pounds per acre of dry matter which contains approximately 5 to 5.5 percent N; thus, fall growth contains, at most, 30 pounds of N per acre. Splitting the nitrogen fertilizer into a preplant and an early spring application has been of value where wheat follows wheat and a large amount of straw has been worked into the seedbed. Most of the nitrogen should be applied when growth starts in the spring. Splitting the nitrogen into two or more spring applications has not increased yields or fertilizer efficiency compared to applying all the nitrogen at one time.

Approximately 100 pounds of straw is produced for each one bushel of wheat (Table 2). The combination of early seeding, nitrogen fertilization in the fall or in the spring before growth has started, and irrigation promotes excessive straw growth. Such wheat may lodge before or during flowering which results in lower grain yield, lower test weight, and poorer milling and baking qualities. For optimum grain yields from well-managed irrigated fields, coordinate planting, fertilizing, and irrigating so plants develop only a few tillers and crown roots in the fall. Such plants will be large enough to have good winter survival. Larger plants are desirable where water or wind erosion is a problem. In the spring, a large supply of nitrogen starting with late tillering develops many tillers into stems and heads and a large upper leaf area essential to many and large kernels.

Table 2. Average levels of nitrogen and sulfur in grain and straw of a 50- and 125-bushel wheat crop

	Yield	Nitrogen		Sulfur	
	lbs/acre	%	lbs/acre	%	lbs/acre
50 bushels					
Grain	3,000	1.60	48	0.14	4.2
Straw	4,750	0.50	24	0.07	3.3
Total	7,750				
125 bushels					
Grain	7,500	1.65	124	0.14	10.5
Straw	12,500	0.50	63	0.07	8.8
Total	20,000		187		19.3

Reduced Tillage

Reduced tillage systems initially require larger rates of fertilizer than conventional tillage systems. The slower decomposition of straw with reduced tillage "ties up" nutrients longer than where there is tillage incorporation of the straw. To avoid nutrient deficiencies, up to 20 percent additional nitrogen and sulfur should be applied to each crop for six to eight years after starting reduced tillage. Complete no-till systems may not require any additional nitrogen and sulfur when the fertilizer is banded below the seed. Broadcast application of fertilizer in no-till systems is not recommended as it has shown poor efficiency.

Source of Nitrogen

There is little or no difference in nitrogen sources if each is properly applied. Seven nitrogen fertilizers were broadcast or sprayed in early spring in four separate experiments (Table 3). Each material applied at the rate of 40 pounds of nitrogen per acre increased the wheat yield approximately 10 bushels per acre. These results agree with information in other areas.

Table 3. Grain yield response of wheat fertilized with different sources and forms of nitrogen

Source of nitrogen[1]	Grain
	bu/acre
Ammonium nitrate granular	43
Ammonium sulfate granular	42
Urea granular	43
Urea solution	43
Urea-ammonium nitrate (Solution 32)	40
Urea-ammonium nitrate granular	41
Calcium nitrate granular	44
No N fertilizer	33

[1]Each source of nitrogen was applied in early spring at 40 pounds per acre of nitrogen. Rain occurred within 24 hours after application.

SULFUR

Sulfur deficiency for plant growth is widespread in northeast Oregon. This deficiency is intensified where nitrogen fertilization increases plant growth. Most wheat fields need sulfur if they are fertilized with nitrogen. One exception is where the soil has a high level of soluble salts which usually have a high percentage of sulfates.

Fifteen to 30 pounds of sulfur per acre should be applied at the time nitrogen fertilizer is applied before seeding or in early spring. The sulfur requirement of the wheat plant is approximately one-tenth the nitrogen requirement (Table 2). Most of the sulfur, as well as the nitrogen, is absorbed by the plant before and during the period of rapid spring growth. Slightly more of the sulfur in the mature crop is in the grain than in the straw.

Sulfur deficiencies in wheat are observed most frequently in spring growth after a wet winter and where only nitrogen fertilizer was applied. Most of the sulfate sulfur has been leached below the active roots. Cool, wet weather in the spring increases sulfur deficiency since microorganisms which convert sulfur to sulfate, a form used by plants, are relatively inactive in cool soil.

Visible plant deficiency symptoms of sulfur and nitrogen are very similar; plants are light green to yellowish-green in color. Mild sulfur deficiencies observed in early spring growth disappear with warmer weather; yield loss from these observed symptoms has been difficult to measure. Sulfur deficiency observed in early spring growth can be corrected by an immediate application of 15 to 30 pounds of sulfur per acre in the sulfate form. Rainfall or irrigation is needed to move the applied sulfur into the root zone.

PHOSPHORUS

Phosphorus is not critically deficient for wheat in northeast Oregon except in Baker Valley and the southern part of Union County. Occasionally wheat in other parts of northeast Oregon shows a fall growth response to phosphorus fertilization and yields a few more bushels provided there are no other growth-limiting factors.

Soils mapped as Wingville, Baldock, and Baker and associated soils consistently have low P soil test values and need phosphorus fertilization. This area centers around Wingville but extends northward to near the North Powder River and eastward across the Powder River. Catherine and associated soils near Union and Hot Lake also benefit from phosphorus application. These soils are naturally deficient in phosphorus and have the capacity to "fix" large quantities of applied phosphorus. Soil tests are very helpful in detecting soil low in available phosphorus.

Many of the fields in this area are irrigated, are used primarily for legume or legume-grass forage production, and are rather unusual for northeast Oregon in their response to fertilization. Wheat in these fields will need an application of phosphorus fertilizer or phosphorus plus sulfur but little if any nitrogen. Soils not needing sulfur contain sufficient soluble salts which can be detected by a soil test.

Twenty to 50 pounds of available phosphorus (P_2O_5) per acre should be applied. The best method and time to fertilize with phosphorus are to band the fertilizer during wheat seeding. Twenty pounds per acre of phosphate with or near the seed is as effective as 40 or more pounds per acre broadcast and worked into the seedbed. Little if any nitrogen (no more than 10 to 15 pounds per acre) should be applied directly with the seed if a nitrogen-phosphorus fertilizer is used. More nitrogen can be applied if the fertilizer is banded near the seed.

Methods which work the phosphorus into the soils just before planting are more effective than methods which leave the phosphorus on the soil surface or apply the phosphorus after seeding. Phosphorus is not moved into or within the soil by moisture as are nitrate nitrogen and sulfate sulfur. The most critical time for phosphorus by the wheat plant is immediately after germination and during the early stages of growth.

A soil test is helpful in estimating the available phosphorus in the soil and estimating phosphorus fertilizer needs for winter wheat. The soil sample should be taken from the plow layer or from the upper 12 inches of soil. Yield increases can be expected where the surface soil tests 8 or less ppm (parts per million) available phosphorus. The yield expected should be considered when interpreting the results of a soil test. If a relatively high yield (near or more than 100 bushels per acre) is expected, phosphorus should be applied with a soil test of 12 or less ppm.

OTHER ELEMENTS

Potassium and trace elements have not given a beneficial response on winter wheat in northeast Oregon. Two areas suspected of needing potassium are (1) in the Flora area of northern Wallowa County and (2) a small area northwest of Union in Union County. Soil tests show low available potassium in old lake developed material of peat and peat associated soils in the latter area. In all of northeast Oregon, much more consideration should be given to fertilizing with nitrogen, sulfur, and possibly phosphorus than with potassium and trace elements.

Soluble salts that accumulate or have accumulated in soils with poor drainage are generally a mixture of sodium and potassium salts. High and very high soil test values for available potassium are measured in some salty soils.

TESTS WHICH AID DECISION-MAKING CONCERNING FERTILIZER USAGE

Soil Tests

Standard soil tests of the surface soil (plow layer, 0 to 8 inches, or 0 to 12 inches) for pH, available phosphorus, available potassium, and soluble salts help evaluate the potential productivity of the soil. To date, little use is made of the calcium and magnesium tests since soils in this area appear to be adequately supplied with these elements.

Soil tests for nitrate and sulfate are of value but do have limitations as an aid in deciding how much nitrogen and sulfur fertilizers to apply. Nitrate and sulfate are products of microorganism decomposition of soil organic matter; the rate of decomposition depends on many factors that can change rapidly. Soil temperature and moisture are the two major factors; others are leaching, waterlogging, plant removal, and type of crop residue.

Considerable over-winter change in the nitrate content of the soil and loss of nitrogen applied before planting can occur. Examples of change in soil nitrate with soil depth, time, and fertilization are presented in Tables 4 and 5. In September before planting, most of the nitrate was found in the first foot or two of soil. Less nitrate was measured in the surface foot of unfertilized soil in March than had been measured the previous September. The total amount of nitrate in unfertilized soil in March compared to the previous September varied from approximately twice as much in Field 1 to half as much in Field 4. These data help explain why preplant nitrogen fertilizer is less effective than nitrogen fertilizer spring applied.

Table 4. Soil nitrate-N in non-fertilized soil as influenced by soil depth and time of sampling from planting to harvest of wheat

	Date soil sampled			
Soil depth	September	November	March	August
feet	lbs/acre nitrate-N			
Field 1				
0-1	30	51	19	
1-2	6	10	30	
2-3	2	7	22	
3-4	3	4	7	
4-5	4	3	5	
Total	45	75	83	
Field 2				
0-1	37	20	13	1
1-2	23	32	9	1
2-3	21	27	20	---
3-4	21	40	19	---
4-5	18	25	17	---
Total	120	144	78	

--- = not sampled

Table 5. Soil nitrate-N content as influenced by soil depth, time of sampling, and fertilizer N application

	Date of sampling and N applied[1]			
	September	March		
Soil depth	0 N	0 N	75 N	150 N
feet	lbs/acre nitrate-N			
Field 3				
0-1	33	13	20	13
1-2	20	19	15	19
2-3	9	29	25	20
3-4	4	34	67	39
Total	66	95	127	91
Field 4				
0-1	18	8	16	25
1-2	33	5	12	13
2-3	20	5	13	13
3-4	11	6	14	14
4-5	5	11	21	17
Total	87	35	76	82

[1]Pounds of nitrogen per acre from ammonium sulfate worked into the seedbed before planting in September.

Plant Analysis

Plant analysis has value when used with field observations and knowledge of production practices. Plant analysis usually indicates one of three general levels of a nutrient within the plant--(1) sufficiency, (2) a rather broad area where it is difficult to decide if the plant is adequately supplied or deficient, and (3) deficiency.

Dormant winter wheat contains about 5 percent total nitrogen. During spring and early summer growth, nitrogen is translocated from older leaves into younger leaves and from the upper leaves into the head and grain. The concentration of nitrogen in the whole plant drops rapidly after spring growth starts. Concentration of nitrogen in the plant can be demonstrated in experimental work to be associated with grain yield but must be tied closely with the growth stage of the plant to be of value when using tissue testing as a guide to nitrogen fertilization.

Nitrate concentration in the lower inch or two of wheat stems may increase or decrease during early and mid-tillering in the spring. Nitrate concentration, if high as several thousands parts per million, declines rapidly starting in late tillering or early jointing. Nitrate concentration during late tillering in irrigated wheat appears to be a more reliable guide to the N status of the plant than nitrate concentration during early tillering.

Grain Analysis

Protein content of the harvested grain provides some indication of the nitrogen fertility status of the growing crop or moisture stress as the grain was maturing. Low protein, as less than 9.0 percent, indicates the wheat may have not had adequate nitrogen (Table 1). High protein content, above 11.5 percent, is associated with either of two possibilities: (1) more than adequate nitrogen for optimum growth or (2) adverse growing conditions during the later stages of growth (Table 1). Usually the adverse condition is lack of moisture but it could be disease or lodging.

These soil and plant tests provide information which aid in deciding how much fertilizer to apply. Unfortunately, these tests do not have the reliability and convenience desired and must be tempered considerably with experience and good judgment. Small scale fertilizer trials conducted by the producer in his fields continue to be the best demonstration as to whether profitable yield increases can be obtained.