EM 8963-E
Revised June 2009

Soft White Winter Wheat

(Western Oregon)

J.M. Hart, M.D. Flowers, R.J. Roseberg, N.W. Christensen, and M.E. Mellbye

Soft white winter wheat is the most important nonirrigated crop grown in western Oregon. It is grown in a variety of rotations and landscape positions. The most yield-limiting nutrient for this crop usually is nitrogen. Liming to increase soil pH is sometimes necessary, as well as addition of sulfur, phosphorus, potassium, and magnesium.

This guide provides nutrient and lime recommendations for soft white winter wheat established after conventional tillage or with direct seeding on the Willamette Valley floor, on low hills bordering the valley, and in other Oregon valleys west of the Cascade mountain range in Benton, Clackamas, Douglas, Jackson, Josephine, Lane, Linn, Marion, Polk, Washington, and Yamhill counties.

Healthy plants with adequate root systems are required to obtain the greatest return from your fertilizer investment. The nutrient recommendations in this guide assume that adequate control of weeds, insects, and diseases is achieved. Lack of pest control cannot be overcome by the addition of nutrients.

Common pest problems for wheat production in western Oregon are take-all root rot, Septoria leaf and glume blotch, stripe rust, slugs, cereal leaf beetle, aphids, grassy weeds (such as annual ryegrass and wild oats), and broadleaf weeds (such as bedstraw, speedwell, and thistles). The box at right, “Reduction in wheat yield when disease is not controlled,” provides an example of wheat yield loss from disease.

The average grain yield of soft white winter wheat in western Oregon is approximately 100 bu/a. The recommendations in this guide, especially for nitrogen, are adequate to produce higher yields. For example, yields of 140 bu/a or greater can be produced with these recommendations on sites where soil pH and drainage do not limit yield.

The recommendations in this guide are based on research conducted during the past 50 years on both large and small plots throughout western Oregon.

J.M. Hart, Extension soil scientist; M.D. Flowers, Extension cereals specialist; R.J. Roseberg, research agronomist; N.W. Christensen, professor of soil science; and M.E. Mellbye, Extension agronomist, Linn County; all of Oregon State University.

Soft white winter wheat harvest in western Oregon (Washington County).

Reduction in wheat yield when disease is not controlled

Figure 1 shows that wheat yield increases with increasing N rate until 100 lb N/a is applied, both with and without fungicide application. However, wheat yield is consistently greater when fungicides are used than when they are not. Apply the amount of N needed to obtain the yield potential, and control diseases so that yield potential is reached.

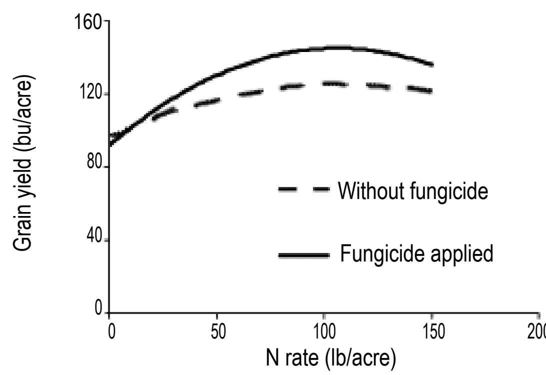


Figure 1.—Wheat yield increase from N and impact of fungicide application in the presence of disease. The fungicide was applied to ‘Stephens’ wheat at the end of April 1987, just as the flag leaf began to emerge. The field was near St. Paul, Oregon, and produced bush beans the year before wheat was planted.

Oregon State University Extension Service

Management decisions before planting

Rotation

Wheat may be grown in rotation with vegetables for processing, peppermint, grass seed, legumes, or specialty seed crops. The previous crop or rotation can limit wheat yield where the risk of soilborne disease (such as take-all root rot) is high, or where the surface soil pH is low after production of a grass seed crop. If you are considering planting consecutive wheat crops, see "Growing wheat with the risk of take-all root rot," below, as this disease can reduce grain yield by 50 percent or more. For more information about managing wheat with take-all root rot, see OSU Extension Service publication EC 1423-E, *Combating Take-all of Winter Wheat in Western Oregon*.

Field selection

Select a field that will provide drainage even after heavy rain events during wet winters. Wheat does **not** tolerate "wet feet." Complete stand loss has occurred when the entire wheat plant was underwater for 7 or more consecutive days. Losses from shorter periods of flooding are primarily determined by crop condition. Stressed plants—late-planted, cold-injured, those consistently in waterlogged soils, etc.—are typically less tolerant of water coverage. For more information, see "Planting in

Growing wheat with the risk of take-all root rot

Take-all disease of wheat is caused by the soilborne fungus *Gaeumannomyces graminis* var. *tritici*, which infects the roots, crown, and basal stem of plants (Figure 2). Take-all root rot is common in western Oregon whenever consecutive crops of wheat are grown. Grain yield might be reduced by as much as 50 percent in second or third crops of continuous winter wheat.

Few, if any, corrective measures are available after identifying a severe take-all root rot infestation. The following recommendations will minimize yield loss to take-all root rot when successive wheat crops are planted for less than 5 years. See OSU Extension Service publication EC 1423, *Combating Take-all of Winter Wheat in Western Oregon*, for more information.

Field selection is extremely important if take-all root rot may be a problem. If wheat will be grown for 2 or more consecutive years, choose a field with soil pH between 5.4 and 5.8. Yield loss from take-all increases when the soil pH is above 5.8. Fields used to produce vegetable crops, clover, or sugar beets for seed usually have a soil pH above 5.8.

Preplant management

Liming

A soil pH of 5.5 is desirable for combating take-all. Apply lime only if the soil pH is 5.2 or less.

Stubble

Chop stubble and plow deeply to bury the inoculum.

Planting

Planting date

On well-drained valley floor soils, delay planting until late October if possible. Do not delay planting beyond mid-October on hill soils or valley floor soils with reduced drainage. For more information on wheat production on poorly drained soils, see OSU Extension Service publication FS 269, *Growing Winter Wheat on Poorly Drained Soil*.

Fertilization

Band 20–30 lb N/a in ammonium form, 30–50 lb P_2O_5/a, and 10–15 lb S/a. Apply 25–30 lb K_2O/a if a soil test indicates the need for K.

Growing season

Fertilization

Use the "Nmin" soil test to determine spring N rate (see page 9). For more information about the Nmin soil test, read *Using the Nitrogen Mineralization Soil Test to Predict Spring Fertilizer N Rate*, FS 334-E. Apply N as ammonium sulfate plus 100 lb Cl/a as KCl before Feekes growth stage 5 (see page 8). Alternatively, apply 40 lb N/a and 100 lb Cl/a at late tillering (Feekes 4; mid-February) and the remaining N within 3 to 4 weeks, but before jointing (Feekes 6).

Weed control

Control weeds to minimize competition with wheat for nutrients and moisture.

Disease control

Control leaf diseases such as Septoria and other root diseases by using resistant cultivars or fungicides. Maintaining plant health is important to ensure maximum benefit from other aspects of this management plan to reduce yield loss from take-all. Read and follow fungicide label directions.

Figure 2.—Wheat field with take-all disease.

poorly drained soil" (below) and OSU Extension Service publication FS 269, *Growing Winter Wheat on Poorly Drained Soil*.

Increasingly, winter wheat is planted without tillage (no-till or direct-seed) as a rotation crop with perennial and annual grass seed crops. Where fields are vulnerable to soil erosion because of slope, direct seeding is common.

If wheat will be planted without tillage in a field that has not recently received tillage, take a shallow soil sample (from the surface to 2–3 inches deep) to determine soil pH. When fields are not tilled for as few as 3 years, soil pH in the surface declines, sometimes to levels that inhibit germination, growth, or both. See the section on "Lime, calcium, and magnesium" (page 6) for more information.

Improved drainage and liming allow good wheat yields to be produced on sites once considered marginal for wheat production because of poor drainage or low soil pH. See "Soils and settings for wheat production" (page 4) for more information about soil suitable for wheat production.

Variety selection

Nutrient recommendations in this guide assume that an appropriate variety is selected for the site. Select wheat varieties with agronomic and quality characteristics that match the growing environment. In western Oregon, consider varieties with good disease resistance and high yield potential. Diseases such as stripe rust and Septoria leaf

Planting in poorly drained soil

In poorly drained soils, seedlings growing on low ridges usually develop normal crown root systems because oxygen supplies are sufficient during the winter (Figure 3). Poorly drained soils have low oxygen levels because the air spaces in the soil are filled with water throughout the rainy season. Oxygen is required for normal root growth; root development is restricted when the soil remains flooded (Figure 4). See OSU Extension Service publication FS 269, *Growing Winter Wheat on Poorly Drained Soil* for more information.

Sufficient drainage can be created with ridges or "beds" made before planting (Figure 5). In theory, a bed of any height will work as long as the water can run into the furrow. In practice, a minimum of 3 inches from the bottom of the furrow to the top of the bed is needed. No matter how high the bed, complete stand loss is possible if the bed is underwater for 7 or more consecutive days. Losses from shorter periods of flooding are primarily determined by crop condition.

Variety selection is important as well. 'Yamhill' is the best cultivar for wetter fields. In drill strip trials, 'Yamhill' wheat has a yield potential of 85–90 percent of the top-producing varieties.

Figure 3.—Fall growth of wheat planted in poorly drained field with ridges.

Figure 4.—Even when tile drains are installed in some poorly drained fields, wheat may die or be injured by standing water in wet years. Tile drain is below green wheat. Yellow wheat is between drain lines.

Figure 5.—Wheat planted in poorly drained field with ridges in midwinter. Water is confined to furrows, allowing adequate oxygen to wheat roots in most of the field.

Soils and settings for wheat production

Soft white winter wheat requires better drainage than grass seed crops, but it is grown successfully on a broad range of soil and landscape positions in western Oregon. The majority of wheat in the Willamette Valley is planted on Amity, Woodburn or Willamette, Chehalis, Malabon, McBee, and other soil series characterized as either moderately well-drained or well-drained. Most of these fields have some relief or "roll" that provides drainage. Many fields have tile installed to improve surface and internal drainage. Tiling is common on the river bottom areas along the Willamette and Santiam rivers as well as on some steeper hill soils along the east and west sections of the valley.

Foothill soils include mostly the Nekia series along the valley foothills. Fields may be located on Hazelair, Helmick, and Steiwer soil series on the west side of the Willamette River. Soils are relatively shallow on many of these fields, and rock outcroppings can pose tillage problems. Proper tillage and planting are critical to protecting steep slopes from soil erosion, especially during fall seeding and the seedling stage. On the east side of the valley, fields can be located at elevations approaching 1,000 ft and rainfall can be 50 percent greater than on the valley floor.

In the southern part of the Willamette Valley, wheat is grown with increasing success on somewhat poorly drained soil types such as Dayton. A combination of management practices has made this change possible. Increased use of lime and fertilizer, along with returning the full straw load, has removed soil pH and nutrient limitations on many grass seed fields. Good surface ditching and tiling are essential. In addition, the use of no-till following grass seed crops, especially where the full straw load was chopped, has allowed successful winter wheat production on fields once considered too wet for grain production. No-till eliminates disturbance of soil structure and tilth that develop in a grass seed field, thus maintaining aeration and drainage on soils that are marginal for wheat production (Figure 5). However, some poorly drained grass seed fields are on landscape positions that pond or remain saturated for long periods of time, severely limiting wheat production regardless of drainage efforts or planting method.

In Douglas County, suitable soils for wheat production are Darby and Nonpareil. In Jackson County, wheat is planted in soil derived from two very different parent materials. In some areas, granitic parent material results in sandy loam soils such as Central Point sandy loam. These soils are easily tilled, but tend to have low native phosphorus (P) and low water-holding capacity, requiring frequent irrigation for good yields of most crops. These soils are excellent for annual crops receiving frequent tillage, such as vegetables and specialty seeds.

Planting wheat in the southern Willamette Valley.

The other primary soil type in Jackson County is derived from basaltic parent material, resulting in soils with moderate to high clay content and shrink–swell capacity, such as Carney clay and Coker clay. These soils are more difficult to till except under narrow moisture ranges, but tend to be high in native P. In the past, many productive acres of small grains and other agronomic crops were grown in Medford loam soil, which is derived from a mixture of both parent materials and exhibits a very good compromise of the physical and chemical characteristics of each.

In Josephine County, many soils are derived from ultramafic parent materials, resulting in loamy and stony soils that are moderately to strongly serpentine. Serpentine soils tend to be high in magnesium (Mg) and metals such as nickel (Ni), cobalt (Co), and zinc (Zn). They tend to be very low in native calcium (Ca), P, and sulfur (S), but typically have a suitable pH for most crops. Crops grown on serpentine soils usually benefit from addition of Ca, P, and S. Since soil pH is usually adequate, Ca is supplied with gypsum rather than lime. Typical Josephine County soils used for agriculture include Brockman clay loam, Kerby loam, and Holland sandy loam, all found along alluvial fans of the Illinois River and its tributaries and all traditionally used for wheat production.

The mineralogy of the clay soils in Jackson County and serpentine soils in Josephine County is different, but both tend to strongly hold available P. As a result, observations have suggested that these soils typically require about twice as much added P to achieve the same crop yield or growth compared to the sandy loam soil in Jackson County and soils in other parts of western Oregon. See "Using the P soil test in Jackson County and southwestern Oregon" (page 7) for more information.

blotch are common and may limit yield in susceptible or less resistant varieties.

Further information on the agronomic and quality characteristics of common winter wheat varieties as well as variety performance can be found on the Oregon Elite Yield Trials website at http://cropandsoil.oregonstate.edu/wheat/state_performance_data.htm

Planting date

Plant in mid- to late October after a period of cool temperatures, which reduce aphid populations and the risk of barley yellow dwarf virus (spread by aphids). If planting earlier, an insecticidal seed treatment is recommended to reduce the risk of aphid-spread diseases. Planting wheat in late September or early October also increases risk of stand loss from freezing temperatures occasionally experienced in early December.

Winter wheat must be exposed to cold temperatures, or vernalized, to trigger head formation. Vernalization requirements vary among cultivars. 'Goetze' has little to no vernalization requirement; 'Madsen', 'Stephens', and 'Tubbs' have intermediate vernalization requirements; and 'Yamhill' has a high vernalization requirement.

For varieties with low to intermediate vernalization requirements, planting as late as mid-February may be successful, although yields will be reduced. Avoid late planting for varieties with a high vernalization requirement. If winter wheat is not planted before January, consider planting a spring variety instead.

Fall nutrient management

Sample and analyze soil to estimate the need for lime, phosphorus, potassium, calcium, and magnesium. Annual soil tests are not necessary for these nutrients—sampling and testing soil every other year or every third year is sufficient. If possible, sample soil after tilling and at the same time of year as previous soil tests. A single sample should represent no more than 40 acres, a single soil type, or an area in the field with the same management practices.

If you have questions about sampling or testing soil, contact your local Oregon State University Extension office or refer to OSU Extension Service publications PNW 570-E, *Monitoring Soil Nutrients Using a Management Unit Approach,* and EM 8677, *Laboratories Serving Oregon: Soil, Water, Plant Tissue, and Feed Analysis*.

Nitrogen

Broadcast a small amount of nitrogen (N), 20–30 lb N/a, before planting or band this rate at planting. Banding fertilizer near or with the seed is an efficient method for delivering a small amount of nutrient. The N may be applied in conjunction with other nutrients such as potassium, phosphorus, and sulfur in a "starter" fertilizer. Placing fertilizer with the seed may delay emergence, sometimes by almost a week, and in dry years can reduce the stand.

Nitrogen application at planting is important in rotations such as wheat following oats, wheat, or other crops that leave little residual N. Insufficient N during early growth limits tiller development (Figure 6). Figures 7 and 8 illustrate the relationship between N at planting, previous crop, and wheat grain yield.

When N was not applied in the fall (Figure 7), the wheat crop following oats never recovered from N deficiency early in the growing season. When 20 lb N/a was applied in the fall (Figure 8), grain yield was similar following both crops. When starter N was applied, the wheat crop following oats had sufficient early N. Early growth was not limited, and wheat yield was equal to or greater than that following clover when adequate spring N was applied (90 lb N/a or more).

Figure 6.—Wheat on left did not receive N at planting. Wheat on right received N in a band at planting.

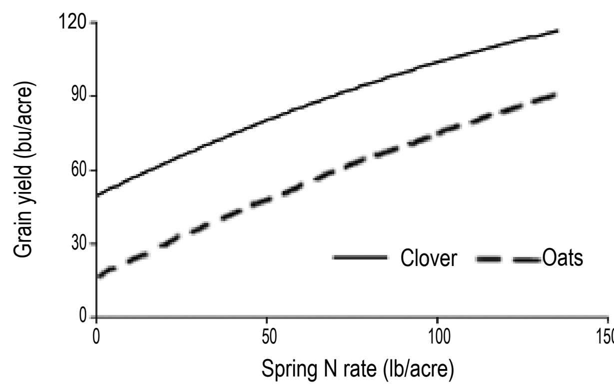


Figure 7.—Grain yield of wheat following oats or clover when no fall or starter N was applied.

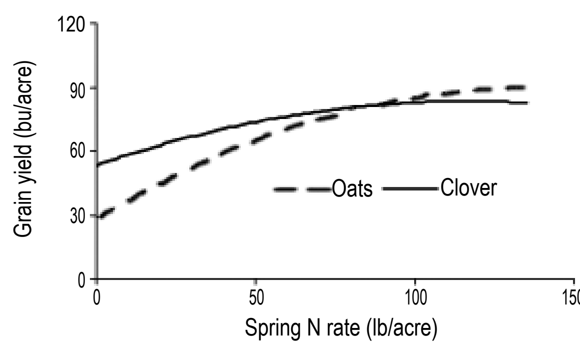


Figure 8.—Grain yield of wheat following oats or clover with fall or starter N application of 20 lb N/a.

Lime, calcium, and magnesium

Acidity or pH is the most commonly measured chemical characteristic of soil. Soil pH indicates the chemical condition roots will experience. A decrease in soil pH is accompanied by the increase in solubility of iron, zinc, manganese, copper, and aluminum. The concentration of aluminum can reach levels that inhibit root growth.

Winter wheat tolerates moderately acidic soil (pH 5.4). However, wheat yields are markedly reduced if the soil pH is less than 5.0 (Figure 9). Soil pH indicates whether soils are too acidic and lime is needed. Wheat yield can be increased by liming soil to increase pH, but yield probably will not increase if soils are limed above pH 5.7. Lime application is not recommended if the soil pH is above 5.8, especially if the risk of take-all is high, as yield loss from take-all increases when the soil pH is higher.

The Shoemaker-McLean-Pratt (SMP) buffer or lime requirement test (LR) estimates the amount of lime needed to raise soil pH. Lime application rates can be estimated from Table 1. Sometimes sandy or river bottom soils such as Newberg have less than 5 meq Ca/100 g soil and a lime rate of 1 ton/a is recommended.

Table 1.—Lime rate recommendations for western Oregon using the SMP buffer. Note that SMP buffer is different than, and does not equal, soil pH.

SMP buffer test result*	Apply this amount of lime** (ton/acre)
Below 5.5	3–4
5.5–5.8	2–3
5.8–6.2	1–2
Over 6.2	None

*Lime recommendations are based on SMP buffer test only. If other buffer tests are used, recommendations may differ. Liming rates cannot be determined based solely on soil pH.

**Lime rate is based on 100-score lime.

Sample and test soil for pH, SMP buffer lime requirement, and calcium (Ca) well before planting, because lime should be mixed into the seedbed before seeding. A lime application is effective for several years.

Soil pH changes naturally between seasons by as much as 0.3–0.5 unit. It is lowest in late August and September, before the fall rains begin, and highest in February or March, when the soil is wettest. Sample soils for pH at the same time each year to avoid confusion from seasonal fluctuation.

See OSU Extension Service publication FG 52-E, *Fertilizer and Lime Materials*, for more information about liming materials.

Although wheat yield increase from application of magnesium (Mg) has not been documented in western Oregon, we advise adding magnesium if soil test Mg is below 60 ppm or 0.5 meq/100 g soil. Magnesium can be supplied from dolomitic lime or fertilizers such as Sul-Po-Mag and K-Mag. These materials also supply sulfur. A band application of 10–15 lb Mg/a is sufficient.

Figure 9.—Low soil pH reduces wheat growth and vigor unevenly in a field. The areas that have light green wheat and sparse growth are growing in soil with a pH of 4.3. The soil pH is higher in the areas with darker green wheat.

Sulfur, phosphorus, and potassium

Banding phosphorus (P), potassium (K), sulfur (S), and some nitrogen (N) fertilizer with or near the seed at planting is an effective method of fertilizer application for small amounts of nutrients, especially immobile nutrients such as P and K. Placing fertilizer with the seed will delay emergence and in dry years can reduce the stand. Do not apply more than 25 lb K_2O/a and 25 lb N/a with the seed.

These nutrients are discussed below in order of importance (the likelihood they will limit wheat grain yield if deficient).

Sulfur

Grain yield increase from S application is site- and year-specific. No soil test adequately predicts soil S supply. Our approach is to place the likelihood of yield increase from S applications in three categories—low or none, normal, and high.

Little or no S is needed when wheat follows vegetable or legume crops that received 30–40 lb S/a for several years. If growers wish to ensure adequate S is present in this situation, 10–15 lb sulfate-S/a can be applied with spring N.

Sulfur is likely to limit grain yield in fields that did not receive S the previous year. In this situation (as for most rotations), ample S is provided from application of 10–15 lb sulfate-S/a at planting time.

The need for S is highest if wheat or oat straw is incorporated. In this situation, preplant broadcast and incorporate 10–15 lb S/a and then band the same amount at planting. When straw is incorporated, sulfur is "tied up" or immobilized, similar to nitrogen. Wheat grain yield may decrease by as little as 3–4 bu/a to as much as 15–20 bu/a in the second year when only 10 lb S/a is banded and no additional S is applied, compared to yields when S is broadcast preplant and banded at planting.

Phosphorus

Growers know that adequate P is essential for maximum yields. Therefore, P is routinely applied. As a result, P soil test values in fields typically are quite high. For soils with a P soil test value above 30 ppm, reducing or eliminating P application will increase profit.

Phosphorus is especially important for early growth of most crops in the grass family, including small grains and corn. Deficiency during the seedling stage can severely limit yields. Is P fertilizer always needed? The answer is no. Applying P at planting when P availability is low due to cool, wet soil conditions is important. When soil tests indicate high amounts of P (> 30 ppm), and soils have adequate temperature and aeration for growth, wheat yield does not increase from application of P fertilizer.

Using the P soil test in Jackson County and southwestern Oregon

Interpretation of soil tests varies geographically primarily because soil parent material and the growing environment are different across the landscape. The same soil test, such as the Bray test for phosphorus (P), must be interpreted differently when the parent material of the soil is markedly different. The soil test itself does not provide a fertilizer recommendation—our interpretation of the soil test results lead us to propose a fertilizer recommendation.

This situation is true for western Oregon, where some serpentine soils in Josephine County and soils with high clay content in Jackson County have a greater ability to hold and compete with plants for available P. These soils require more P for optimum yield than do soils in other areas. In Jackson and Josephine counties, use the following table for P fertilizer recommendations based on soil test P.

Fertilizer phosphorus rate recommendations for Jackson and Josephine counties using the Bray P1 soil test.

Soil test P* (ppm)	Apply this amount of P_2O_5 (lb/a)
0–10	60–80
10–40	30–60
Over 40	None

*Bray P1 soil test method.

Phosphorus recommendations in Table 2 are for banding near the seed at planting. An alternative P recommendation table for Jackson and Josephine counties is found in the box "Using the P soil test in Jackson County and southwestern Oregon."

Table 2.—Fertilizer phosphorus rate recommendations for western Oregon using the Bray P1 soil test.

Soil test P* (ppm)	Apply this amount of P_2O_5 (lb/a)
0–20	40–60
20–30	30–40
Over 30	None

*Bray P1 soil test method.

The one exception to using soil test results to determine the need for P application is when take-all root rot is expected. We then recommend banding 30–50 lb P_2O_5/a at planting. With take-all root rot present, wheat grain yield increased from 56 to 65 bu/a when P was banded with the seed on a Willamette soil with a Bray P1 soil test of 125 ppm—a statistically significant and profitable 9 bu/a increase from P application. See the box "Growing wheat with the risk of take-all root rot" (page 2) for more information.

Potassium

Soil test K results and the need for potassium fertilizer are often related to crop rotation. When wheat is grown in rotation with a crop that removes several tons of dry matter/a, such as peppermint or grass seed with baled straw, large amounts of K are removed with the harvested crop. The removal of several tons of stalks and leaves reduces K soil test values. If straw is left in the field, K fertilizer requirements usually are reduced or eliminated.

If a soil test indicates potassium fertilization is required, 25–30 lb K_2O/a can be placed with the seed. Placing fertilizer with the seed will delay emergence and in dry years can reduce the stand. If normal rainfall and soil moisture aren't present, delay planting until adequate moisture is present or eliminate K in the fertilizer band. If higher rates of K fertilizer are desired, apply the fertilizer before seeding and work it into the seedbed.

Table 3.—Fertilizer potassium rate recommendations for western Oregon using the ammonium acetate soil test.

Soil test K* (ppm)	Apply this amount of K_2O (lb/a)
0–75	60–100
75–100	30–60
Over 100	None

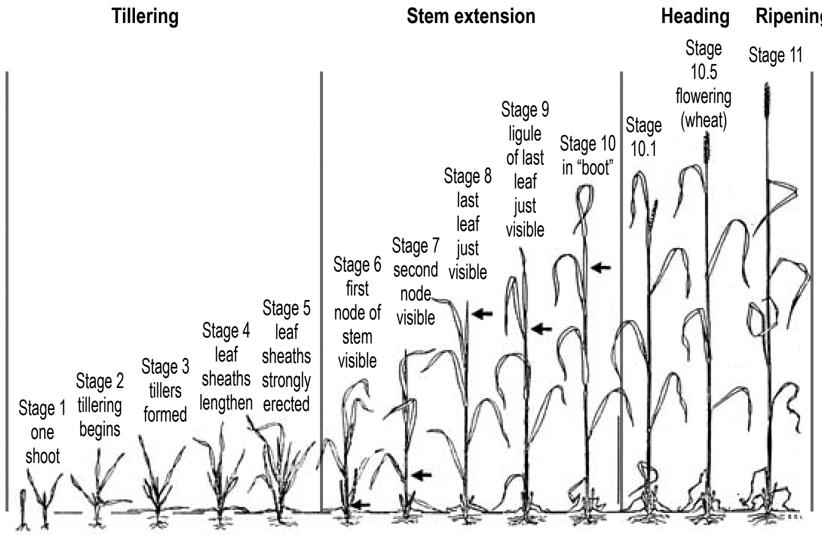
*Ammonium acetate soil test method.

Wheat grain yield and nitrogen

Wheat yield is a combination of number of heads per unit area, kernels per head, and kernel weight. Both head number and kernels per head are set early in wheat development (Feekes growth stages 2 through 5). Banding 20–30 lb N/a at planting supplies sufficient nitrogen (N) for growth and development through these stages.

Nitrogen supply at jointing or stem elongation (Feekes growth stage 6) is critical for further plant development and optimum yield. Maximum N uptake occurs during this period of rapid growth and continues until head emergence (Feekes growth stage 10.1). Nitrogen stress during this period will reduce yield. Apply N fertilizer before jointing (Feekes growth stage 6) to optimize yield.

Growth stages in cereals



Calendar dates are not reliable predictors of jointing, as temperature (accumulating heat units) controls wheat development. Date of jointing will vary by variety, planting date, and growing conditions. In western Oregon, jointing typically occurs in the latter half of February to the middle of March. However, during extremely warm and mild winters it may occur in early February, or in very cold winters it may occur as late as early April. A degree-day calculator is available online at http://pnwpest.org/wea/

Kernel weight is determined by the amount of N present in the plant and, to a lesser degree, the N present in the soil at head emergence (Feekes growth stages 10.1–10.5).

Micronutrients

Wheat yield in western Oregon has not been observed to increase from applications of micronutrients such as boron, manganese, or zinc. Application of chloride may play a positive role when plants are stressed, especially by take-all root rot. Chloride deficiency has been linked to physiologic leaf spot in wheat, which decreases grain yield in eastern Oregon.

Spring nutrient management

Two questions are asked about spring N application: when to apply the N, and how much N to apply. We will consider N timing, or when to apply, first. For more information about the need for nitrogen during the growth of wheat, see the box above, "Wheat grain yield and nitrogen."

N timing, or when to apply

Use plant growth and development and not the calendar as a guide to determine when to apply N. Wheat growth and development is illustrated in the box above. Application of spring N prior to Feekes growth stage 6 (jointing) is critical because rapid N uptake begins at this stage. In western Oregon, jointing typically occurs between mid-February and mid-March, but can begin as early as the first of February or as late as the first of April. Wheat grain yield decreases 10–15 bu/a when spring N application is delayed until late March or early April.

A small amount of N (20–40 lb/a) is accumulated through the end of tillering (Feekes growth stage 5). As jointing and stem elongation begin (Feekes growth stage 6), N is rapidly accumulated by the plant. In a 5- to 8-week period, wheat takes up 100–150 lb N/a, with a peak N uptake rate of 2–3 lb N/a/day during jointing (Figure 10, page 9). By the boot stage (Feekes growth stage 10), the plant has accumulated the majority of the N it will take up, but only about half of its biomass (Figure 10). As grain begins to form, N is moved from the leaves and stems to the head.

An adequately fertilized wheat crop will not produce additional yield if fertilized with N after Feekes growth stage 8 (the appearance of the flag leaf). Late-season N fertilization has been shown to increase grain protein—an undesirable effect in soft white wheat. In addition, late-season N fertilization increases the risk of N loss to the environment.

Growers often wonder whether splitting the spring N application is better than applying it all at one time.

Although you can choose from several approaches, research has demonstrated that grain yield is similar regardless of whether a single application of N is made in February or March or N is split among multiple applications, as long as some N is applied in February or March (see Table 4).

If you do not want to risk leaching loss of N with a high rate (more than 140 lb N/a in late February), split application is a good option; apply 40 lb N/a at Feekes growth stage 3 or 4 and 100 lb N/a within the next month. This N application schedule provides a small amount of N during tillering; the remainder is made available before jointing. Splitting N application can be beneficial where substantial early-season losses are expected, such as wheat grown on sandy soils with high rainfall.

Split N application is also appropriate if urea-ammonium nitrate liquid (Solution 32) is used to supply N. Liquid N is commonly applied with a midwinter herbicide application and should be counted in the total N applied. A single application of a high rate of Solution 32 is likely to injure or burn the wheat.

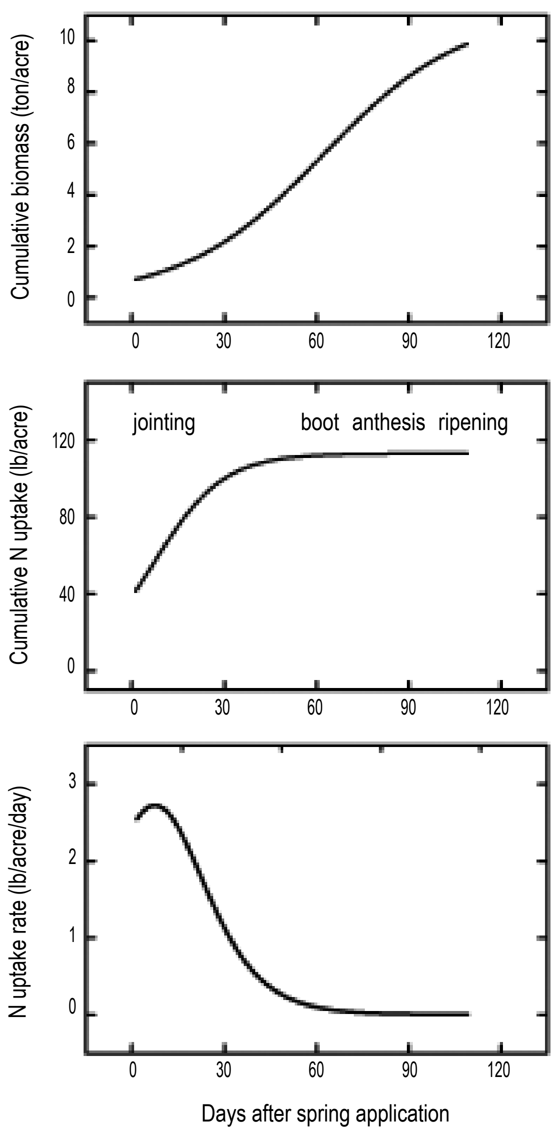


Figure 10. Biomass accumulation and N uptake for winter wheat grown in western Oregon over one growing season. Day 0 is approximately March 1 (Feekes growth stage 3).

Table 4.—N timing influence on yield of 'Stephens' wheat (Central Point, Oregon).

N application date			Grain yield
February 10	March 10	April 11	
N rate (lb/a)			
120	0	0	88
0	120	0	91
0	0	120	75
60	60	0	91
60	0	60	92
0	60	60	88
40	40	40	90

N rate, or how much to apply

Determining the amount of N to apply is a challenge because wheat is produced in numerous rotations that provide varying amounts of N to the wheat crop. Inadequate N results in reduced yield. However, excess N increases lodging, grain protein, production costs, and the potential for N loss to the environment. Wheat following some vegetable crops, tall fescue, or perennial ryegrass grown for seed may require a minimal amount of N (80 lb/a).

Wheat obtains N from two sources: soil and fertilizer. Soil N is provided in available mineral form (nitrate or ammonium-N) and as mineralizable N (nitrogen contained in organic matter; this N will become available during the growing season). The "Nmin" soil test measures both available and mineralizable N and can be used to accurately calculate the spring fertilizer N rate for winter wheat.

Several research projects from 1998 through 2003 evaluated the N mineralization test to predict spring N rate. No reduction in grain yield was measured when the N mineralization test was used to predict spring N rate. In these studies, soil samples were taken in late January and N was applied before stem elongation began. Timely soil sampling and N application are required in order to maintain yield.

Determining spring N rate using the N mineralization soil test has not been verified in Douglas, Jackson, and Josephine counties. Use it with caution in these counties!

Using the Nmin soil test

The first step in using the Nmin soil test is to collect a composite soil sample. Take soil samples during the last 2 weeks of January. Sampling during this period allows enough time for analysis of the soil sample (about 2 weeks) and calculation of fertilizer needs before application of N fertilizer at Feekes growth stage 5.

Sample to a depth of 12 inches and include a minimum of 20 soil cores representing the area to be fertilized. Keep the sample cool until it is delivered to the laboratory. Request three analyses from the laboratory: (1) ammonium-N, (2) nitrate-N, and (3) mineralizable N. Be sure the laboratory you choose can provide all analyses—not all laboratories offer a test for mineralizable N by anaerobic incubation. Request that analyses be expressed in parts per million (ppm) or milligrams per kilogram (mg/kg), not as pounds per acre (lb/a). For a list of analytical laboratories serving Oregon, see OSU Extension Service publication EM 8677.

Using your three N analyses, see Table 5 to select a spring N fertilizer application rate. Table 5 recommends a range of spring N rates from 80 to 200 lb N/a. Even when the Nmin test result is high, a minimum amount of fertilizer N is needed for optimum wheat production. OSU research has shown that 80 lb N/a is the minimum prudent amount to apply (shaded portion of Table 5).

To find a spring N rate using Table 5, be certain that the soil test results are in parts per million (ppm) or milligrams per kilogram (mg/kg). Begin with the Nmin soil test results. Values are found in the left-hand column of Table 5. Follow the Nmin column down until you find the Nmin soil test value closest to yours. Next, add together your soil test NH_4-N and NO_3-N values. Then, locate the column heading that contains the sum of these values. Move down the $NH_4 + NO_3$ column and to the right from your Nmin value. The number where the row and column intersect is the recommended spring N rate given in pounds of N per acre.

In Table 5, Nmin test values increase by increments of 4 ppm, and spring N rates increase by increments of 20 lb/a. If your Nmin soil test value is between those listed in Table 5, adjust the recommended spring N application rate by 5 lb/a for each 1 ppm Nmin.

For more information about using the Nmin test, see OSU Extension Service publication FS 334-E, *Using the Nitrogen Mineralization Soil Test to Predict Spring N Fertilizer Rate: Soft White Winter Wheat Grown in Western Oregon*.

Table 5.—Recommended spring N fertilizer rates based on the Nmin soil test and extractable soil NH_4-N plus NO_3-N.

Nmin soil test (ppm or mg/kg)	Soil test $NH_4 + NO_3$ (ppm or mg/kg): below 10	10–15	16–20	above 20
	Apply this amount of N (lb N/a)			
12	200	180	165	145
16	180	160	145	125
20	160	140	125	105
24	140	120	105	85
28	120	100	85	80
32	100	80	80	80
36+	80	80	80	80

Application

Western Oregon small grain growers have three equipment options for spring application of fertilizer and pesticide material: aerial application, narrow-tire or "tram line," and wide-tire or "buggy" applicators. A comparison of these systems is given in the box "Application equipment and yield loss," page 11.

Foliar nutrient application

Foliar nutrients are recommended only when nutrient deficiencies are visible in a growing crop and the nutrient can be absorbed through the leaf tissue. This combination is extremely rare in western Oregon.

Some growers advocate foliar nutrient applications for some crops when roots are damaged or yield is high. Research in western Oregon does not support the use of foliar nutrient applications in either of these situations for soft white winter wheat production. Foliar application does not increase wheat yield.

Table 6 contains data from three sites where N and Zn were applied to wheat foliage in April. No yield increase was found. Even when wheat yield was 125 bu/a, foliar nutrient application did not increase yield. In addition, wheat yield was not increased when yield was low due to an infection of take-all root rot (Lane County site).

Table 6.—Wheat grain yield with foliar application of N and Zn compared to grain yield without application, 1981.

N rate (oz/a)	Zn rate (oz/a)	Date	Grain yield (bu/a): Lane	Marion	Linn
0	0	—	65	102	122
4	1	April	61	78	117
8	3	April	66	87	110
15	5	April	57	—	—

Postharvest evaluation of N

Growers routinely receive grain protein data when wheat is sold. Use this data as a "report card" to check adequacy of N fertilizer rate. Maximum economic yield is associated with grain protein concentrations between 8.0 and 10.5 percent. Grain protein less than 8.5 percent suggests that N may have been inadequate. Grain protein greater than 10.5 percent suggests that N may have been excessive or that yield was limited by a factor other than N.

N, P, K, S content in wheat grain and straw

As wheat producers consider baling straw, they want to know the amount of nutrients in wheat straw. Table 7 provides data for nutrient concentrations in wheat grain and straw, and Table 8 shows the typical nutrient content of a soft white winter wheat crop.

Table 7.—Grain protein and nutrient concentrations in soft white winter wheat grain and straw.*

	Protein	N	P (%)	K	S
Grain					
Range	7–12	1.4–2.3	0.25–0.4	0.38–0.53	0.12
Average	9	1.5	0.33	0.46	0.12
Straw					
Range	—	0.20–0.50	0.02–0.14	0.75–2.0	
Average	—	0.25	0.05	1.3	

*Data from research in western Oregon.

The data in Table 7 are from field experiments performed in grower fields and at Hyslop Research Farm from 1981 through 2003. They represent more than 200 measurements for P, 100 for K, and as few as 15 for S. Grain P, K, and S and straw P values are more consistent than grain and straw N and straw K.

The variability in data from field to field and year to year suggests that you should use these values only for information or for comparison to values measured in your fields, rather than as a basis for fertilizer application rates.

The amount of N, P, K, and S expected in a 100 bu/a wheat crop is given in Table 8. Most of the crop N is in the grain. In contrast, three-fourths of the K is in the straw. Baling straw removes a substantial amount of K.

The amounts of P and K in Table 9 are given in elemental form. To make comparisons with P_2O_5, multiply the P values in Table 8 by 2.27. To compare elemental K data to K_2O, multiply the K values in Table 8 by 1.2.

Table 8.—Nutrient content for a typical soft white winter wheat crop yielding 100 bu/a.*

	N	P (lb)	K	S
Grain (100 bu)	90	20	28	7
Straw (3 ton)	16	3	81	
Crop total	106	23	109	

*Calculated using average concentrations from Table 7 and a Harvest Index of 0.49.

Economics: Should N rate change when N costs or wheat prices change?

When either the cost of nitrogen fertilizer or the price for a bushel of wheat changes abruptly and considerably, growers wonder whether they should adjust spring N rate. Should the N rate be reduced when N cost climbs or increased when wheat price increases? The answer is the same for either circumstance—do not change N rate. Table 9 (page 12) illustrates how the cost of N or price for wheat affects the maximum economic rate of nitrogen.

Application equipment and yield loss

Aerial application prevents yield reduction caused by "wheel track" damage of plants. The remaining options—narrow-tire equipment using the same tracks or tram lines and wide-tire, high-flotation buggies—trample or crush some of the crop. Most of the damage to tillering wheat is caused when plants are ripped from the ground. Before jointing, wheat can be trampled or grazed with little damage or yield loss. Applications by buggies after jointing increase yield loss since the plants will not recover from damage.

In a continuously or solidly planted stand, the tram line will crush a row or two of grain. If rows that match the wheel spacing of the narrow-tire applicator are not planted, the tires usually push aside the remaining rows. The undamaged grain will tiller and compensate in growth and yield for the unplanted area. Thus, yield is reduced little, if any, with this system.

Spring N is most commonly applied as granular urea using buggies or three-wheel applicators. Some growers use four-wheel or narrow-wheel applicators. The table below provides comparison of yield loss from both application methods, using data averaged over three locations in each field. Sampled areas did not include corners or turns. Buggy application assumes a 60-ft-wide application; 20 percent of the field will have tracks that have been driven on. If your field has more tracks, especially corners, turns, or areas driven over twice, a greater yield loss will occur.

With a buggy applicator, yield in the tracks was 16–18 bu/a less than in an area with no tracks. Yield loss in the track area from a four-wheel applicator was approximately the same. However, much less area was driven on, so field yield loss was only 2 bu/a with the four-wheel applicator. Wheat yield loss is 4–5 percent greater with a buggy applicator.

Wheat yield loss from applicator tracks in spring.

	Buggy	Narrow-tire applicator
	Wheat yield (bu/a)	
Yield outside track, 1987	119	123
Average yield, 1987	115	121
Yield in track area, 1987	101	110
Yield outside track, 1984	96	—
Yield in track, 1984	80	—

Table 9.—Change in maximum economic spring N rate as influenced by cost of N fertilizer and price for wheat.

Wheat price ($/bu)	N cost ($/lb)				
	0.40	**0.50**	**0.60**	**0.70**	**0.80**
	Maximum economic N rate (lb/a)				
4	108	105	101	98	95
6	113	110	108	106	104
8	115	113	111	110	108
10	116	115	114	112	111

If the wheat price doubles from $4/bu to $8/bu and N cost is constant, the maximum economic N rate increases only 7 lb/a when the N cost is $0.40, and only 13 lb/a when the cost of N is $0.80/lb. In Table 9, most of the changes in maximum economic N rate are less than 10 lb N/a. This change is negligible and is less than the application accuracy of most commercial fertilizer applicators.

The base N rate used in Table 9 was 105 lb N/a, using an N mineralization soil test of 24 ppm and ammonium plus nitrate-N of 18 ppm. The equation used to calculate the maximum economic N rate was derived from an on-farm N rate trial conducted in 1986 in a second-year wheat field where the average yield was more than 110 bu/a.

Plant growth regulators

The use of plant growth regulators on winter wheat is not recommended. Modern winter wheat varieties are semidwarf and selected for good straw strength and lodging resistance. Only under extreme circumstances, such as the application or availability of N greater than 1.5 times the recommended N rate, would the application of a plant growth regulator be advisable.

For more information

Christensen, N.W. and J.M. Hart. Revised 2008. *Combating Take-all of Winter Wheat in Western Oregon*. Oregon State University Extension Service publication EC 1423-E, Corvallis, OR.

Christensen, N.W. and M.E. Mellbye. 2006. Validation and recalibration of a soil test for mineralizable nitrogen. Comm. Soil Sci. Plant Anal. 37:2199–2212.

Christensen, N.W., M.H. Qureshi, D.M. Baloch, and R.S. Karow. 1999. Assessing nitrogen mineralization in a moist xeric environment. Proc. Western Nutrient Mgmt. Conf. 3:83–90. Salt Lake City, UT. Potash & Phosphate Institute.

Goetze, N.R., M. Stoltz, T.L. Jackson, and R.S. Karow. 1999. *Growing Winter Wheat on Poorly Drained Soil*. Oregon State University Extension Service publication FS 269, Corvallis, OR.

Hart, J. 1998. *Fertilizer and Lime Materials*. Oregon State University Extension publication FG 52-E, Corvallis, OR.

Hart, J., N.W. Christensen, M.E. Mellbye, and M.D. Flowers. 2006. *Using the Nitrogen Mineralization Soil Test to Predict Spring N Fertilizer Rate: Soft White Winter Wheat Grown in Western Oregon*. Oregon State University Extension Service publication FS 334-E, Corvallis, OR.

Hart, J. 2006. *Laboratories Serving Oregon: Soil, Water, Plant Tissue, and Feed Analysis*. Oregon State University Extension publication EM 8677, Corvallis, OR.

Jackson, T.L. 1985. Personal communication of unpublished research data.

Kjelgren, R.K. 1985. Fertilizer nitrogen use efficiency by winter wheat in the Willamette Valley. M.S. thesis, Oregon State University, Corvallis, OR.

Oregon Elite Yield Trials. http://cropandsoil.oregonstate.edu/wheat/state_performance_data.htm

Acknowledgments

We thank the following reviewers for their thoughtful advice and assistance during preparation of this publication.

Susan Aldrich-Markham, Oregon State University Extension Service, Yamhill County

Gale Gingrich, Marion Ag Service

T.J. Hafner, Wilbur Ellis Company

Russ Karow, Oregon State University, Department of Crop and Soil Science

John Leffel, JL Consulting

Steven Petrie, Oregon State University, Columbia Basin Agricultural Research Station

Steve Salisbury, Wilbur-Ellis Company

Robert Schroeder, Western Farm Service

Robert Spinney, Western Farm Service

Published May 2008. Revised June 2009.