NUTRIENT MANAGEMENT guide

Tall Fescue Grown for Seed

A nutrient management guide for western Oregon

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Tall Fescue Grown for Seed
(Western Oregon)

Tall fescue is a deep-rooted, perennial, cool-season bunchgrass. The cool, moist winters and warm, dry summers of the Pacific Northwest (PNW) are suitable for seed production of many crops, including tall fescue and other cool-season grass species. The PNW produces about 80 percent of the tall fescue seed used in the United States and about 75 percent of the world supply.

Most PNW tall fescue is produced in western Oregon, where it is grown for turf or forage seed in numerous rotations. See the sidebar "Soils and settings for tall fescue seed production" (page 4) for more information about the production area. Stand longevity commonly varies from 4 to 7 years, depending on the production contract and stand vigor.

This guide provides nutrient and lime recommendations for establishment and maintenance of turf and forage tall fescue grown for seed in western Oregon. Healthy plants with adequate root systems are required to obtain the greatest return from your fertilizer investment. The nutrient recommendations in this guide assume adequate control of weeds, insects, and diseases. Lack of pest control cannot be overcome by the addition of nutrients. Common pest problems for tall fescue seed production in western Oregon include stem rust, slugs, grass weeds (such as annual and roughstalk bluegrass), and broadleaf weeds (wild carrot, common groundsel, mayweed chamomile, speedwell, and chickweeds).

Straw is either baled and removed or finely chopped (flailed) in a timely manner and spread uniformly onto the stand. Straw management

Figure 1.—Tall fescue is grown for turf or forage seed throughout western Oregon.

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considerations and implications for nutrient management are found in *Postharvest Residue Management for Grass Seed Production in Western Oregon*, OSU Extension Service publication EM 9051 (see "For More Information," page 19). Potassium is the only nutrient for which management changes if straw is baled rather than chopped.

Approximately 20 percent of the tall fescue seed produced in Oregon are forage varieties, while about 80 percent are turf varieties. Tall fescue fields are sometimes grazed with sheep, especially forage varieties grown in the southern Willamette Valley. Forage and turf varieties are similar in nutrient requirement; therefore, no distinction is made between them in this guide.

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The most yield-limiting nutrient for tall fescue seed crops is nitrogen (N). Liming to increase soil pH is sometimes necessary, as well as addition of phosphorus (P), potassium (K), sulfur (S), and magnesium (Mg). The average seed yield for tall fescue in western Oregon is 1,500 to 1,800 lb/a. The recommendations in this guide, especially for N, are adequate for seed yields of 2,500 lb/a or higher.

 The nutrient recommendations in this guide are based on experiences of growers and agricultural industry personnel, as well as on research performed for more than 30 years on OSU experimental farms and grower fields throughout western Oregon.

Tall fescue seed yield is sensitive to drought stress during flowering and seed development. Strategic irrigation timing to support flowering and seed filling increases seed yield, even in years when soil moisture is not particularly low (Figure 2).

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Figure 2.—Irrigation can increase yield even in years when soil moisture is not particularly low.

Summary

Before planting

Lime	When soil pH is below 5.5, apply preplant lime according to Table 1. See pages 6–7.
Nitrogen (N)	Apply 20 to 40 lb N/a, broadcasted or in a band. See page 7.
Phosphorus (P)	When soil test P is below 25 ppm, apply P in a band. See Table 2 (page 12).
Potassium (K)	When soil test K is below 150 ppm, apply K. See Table 3 (page 14).
Sulfur (S)	Band 15 to 25 lb S/a at planting. See page 16.
Calcium (Ca)	When soil test Ca is below 5 meq/100 g of soil (1,000 ppm), and soil pH is above 5.0, apply 1 t lime/a. See page 7.
Magnesium (Mg)	When soil test Mg is below 0.5 meq/100 g of soil (60 ppm), substitute 1 t dolomite/a for 1 t lime/a of the lime requirement. See page 7.
Micronutrients	Application of micronutrients is not recommended.

Established stands

Lime	When pH in the surface 2 inches of soil is below 5.5, top-dress 1 t lime/a. See pages 6–7.
Nitrogen (N)	Apply 100 to 140 lb N/a between early February and the first week of April and 30 to 40 lb N/a in early October. See pages 7–11.
Phosphorus (P)	When soil test P is below 25 ppm, apply P according to Table 2 (page 12). A maintenance application is common when soil test P is between 25 and 50 ppm. Application can be made in fall or spring. See pages 11–14.
Potassium (K)	Apply K if soil test K is below 150 ppm. The amount needed depends on residue management practices. See Table 3 (page 14). If soil test K is above 100 ppm, application can be made in fall or spring. If soil test K is below 100 ppm, fall application is recommended.
Sulfur (S)	Apply 15 to 25 lb S/a each spring or 30 to 50 lb S/a every other year. See pages 16–18.
Micronutrients	Application of micronutrients is not recommended.

Crop growth and development

Nutrient rate and timing recommendations are based on plant demand. Tall fescue growth and nutrient uptake patterns help determine fertilizer application timing.

Tall fescue has a greater need to be exposed to low winter temperatures (vernalizaton) to induce flowering than does perennial ryegrass. A spring planting of tall fescue will not flower and produce a seed crop in the first summer after planting. Once induced to flower, tall fescue plants undergo stem elongation in spring much like perennial ryegrass.

Floral induction

Floral induction occurs in response to short day length in late fall and winter, following a sufficient juvenile growth period. Floral induction marks the transition of the central growing point (apical meristem) from vegetative to reproductive status.

Early spring growth (after mid-February) is slow (Figure 4, page 5). However, during this time, floral induction begins, with leaf and axillary buds (the points of origin of the tillers) beginning to undergo changes. Because these changes occur at temperatures lower than those required for plant growth, the initial transition to reproductive status is on a microscopic scale. Only biochemical

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Soils and settings for tall fescue seed production

Tall fescue is grown for seed in western Oregon's Willamette Valley region, including the gently sloping hills bordering the mountainous uplands of the Coast and Cascade mountain ranges in Benton, Clackamas, Lane, Linn, Marion, Multnomah, Polk, Washington, and Yamhill counties. "Western Oregon" is used to collectively describe the area for which recommendations in this publication are applicable.

The combination of productive soil and favorable climatic conditions (wet, mild winters and dry summers) provides a setting for high-quality tall fescue seed production and gives the area a competitive advantage among the world's seed-producing regions.

In the southern, central, and northern areas of the Willamette Valley, tall fescue grown for seed is planted primarily on soils formed in stratified glacio-lacustrine silts such as Amity, Willamette, and Woodburn, and on alluvial soil series such as Chehalis, Malabon, McBee, and Newberg. Most of these fields have some slope that allows water to drain. Tile has been installed on many fields to improve surface and internal drainage.

Soils on the floodplain tend to be well to excessively drained, and in many years supplemental irrigation is required to optimize seed yields. Soils found in these areas include Chehalis, Clackamas, and Newberg series, as well as small areas of other soils.

In the southern part of the Willamette Valley, a combination of management practices has increased the success of growing tall fescue on somewhat poorly drained soil types such as Dayton ("white soil") and Bashaw ("gumbo" or "blue, sticky soil"). In these situations, surface ditching and tiling are essential to promote a soil environment conducive to tall fescue seed production.

Tall fescue is also produced in foothills on the east side of the Willamette Valley, primarily on Nekia,

Jory, and Stayton series. Here, fields can be located at elevations approaching 1,000 feet, and rainfall can be 50 percent greater than on the valley floor. On the west side of the Willamette River, fields are located on Hazelair, Helmick, and Steiwer soil series. Foothill soils can be relatively shallow, and rock outcroppings can pose tillage difficulties. Proper tillage and planting operations are critical to protecting steep slopes from soil erosion, especially during fall seeding and the seedling stage.

In addition to the soil series used for tall fescue seed production in the central Willamette Valley, Aloha, Verboort, Laurelwood, Wapato, Helvetia, and Cove soils formed in loess and mixed alluvium are used for grass seed production in the Tualatin Valley.
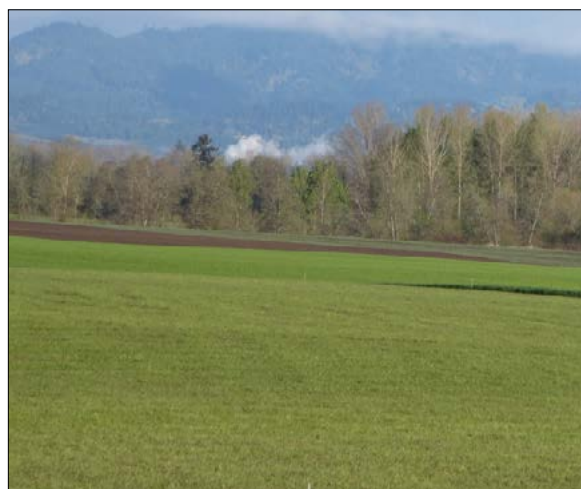

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Figure 3.—Tall fescue and other cool-season grasses are grown for seed in western Oregon's broad, flat Willamette and Tualatin valleys and on the gently sloping hills bordering the mountainous uplands of the Coast and Cascade mountain ranges.

and physiological changes are taking place. These changes are not marked by any externally visible or easily measurable change in the plant.

Eventually, the differentiation between leaf and axillary buds produces a double-ridge appearance on the apical meristem. The transition to reproductive development becomes evident with stem elongation much later in the season as days lengthen in the spring.

Biomass production

Above-ground biomass (growth) in tall fescue varies seasonally. Biomass increases after seed harvest as crop growth begins following fall rains or irrigation. It then slows during the low growing degree days (GDD) of winter. Only 20 percent of above-ground biomass is accumulated by early April, when stem elongation begins.

As stems continue to elongate, biomass accumulation increases dramatically and linearly through mid-June (Figure 4). It reaches a peak at
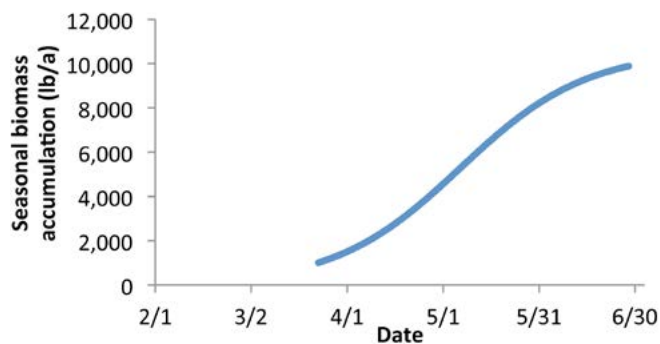
Figure 4.—Seasonal biomass accumulation in established turf-type tall fescue grown for seed in western Oregon. Data from Qureshi (1995); figure by John Hart.
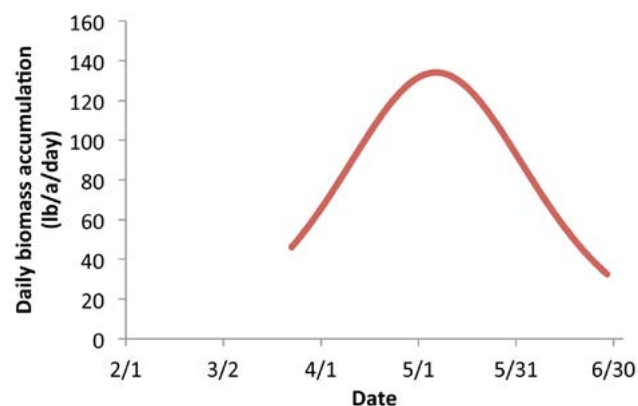
Figure 5.—Daily biomass accumulation in established turf-type tall fescue grown for seed in western Oregon. Data from Qureshi (1995); figure by John Hart.

flowering, when above-ground biomass for forage-type tall fescue can exceed 24,000 lb/a.

Daily biomass accumulation reaches approximately 150 lb/a about the first of May (Figure 5). As the crop attains maximum leaf area and shifts to seed development (early June until harvest), biomass accumulation slows considerably.

Crop biomass production declines with stand age. First-year stands were found to have 23,000 lb biomass/a at flowering, declining to 14,000 lb/a at flowering in the third-year. Biomass production at the end of fall regrowth also declines as the stand ages, from 4,200 lb/a in a first-year stand to 1,600 lb/a in a third-year stand.

Nutrient application and seed yield

Seed yield is a measure of total seed weight per area harvested. Yield depends on two factors: individual seed weight and seed quantity. Seed quantity is determined by the number of florets that are successfully pollinated, fertilized, and produce saleable seeds (Figure 6). Floret number is determined by the number of florets per panicle (the branched inflorescence bearing the spikelets) and especially by the number of panicles per acre. The number of seeds harvested can also be affected by seed abortion during development, as well as by losses during harvesting and cleaning processes.

Figure 6.—Seed quantity depends on the number of florets that are successfully pollinated, fertilized, and produce saleable seeds.

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The objective of fertilizer application in tall fescue seed production is to increase seed yield by manipulating the factors that determine seed weight and quantity and by ensuring sufficient crop canopy to support the photosynthesis required for seed filling. Spring N application consistently increases seed weight and generally increases the number of fertile or reproductive tillers.

Plant growth regulators (PGRs) are used in tall fescue to reduce lodging, in turn possibly increasing seed yield. Using PGRs does not change tall fescue nutrient needs or fertilizer application recommendations. See the sidebar "Plant growth regulators" for more information.

Lime, calcium, magnesium, and pH

Stand establishment can fail if soil pH is below 5.0. *When soil pH is less than 5.5, lime is recommended* (Figure 7). Use Table 1 to determine lime rate based on SMP buffer test results. Do not exceed 5 t lime/a in a single application, even if the SMP lime requirement is greater. For best results, mechanically incorporate lime during seedbed preparation.

To ensure adequate soil pH for the life of a stand and avoid the need for a top-dress lime application, raising soil pH to at least 5.8 before planting is an option. The amount of lime needed to reach this goal is about 0.5 ton more than the

amount indicated in Table 1 to reach a soil pH of 5.6.

Soil pH, especially in the surface 2 inches, decreases as a tall fescue stand ages. Regular soil sampling and testing to monitor soil pH is recommended for established stands. *If soil pH falls below 5.5 in the surface 2 inches, top-dress with 1 t lime/a.* Top-dressed lime applications should not exceed 2 t/a. Top-dressing lime without incorporation raises soil pH in only the surface inch of soil.

Seasonal fluctuation of soil pH makes year-to-year comparisons difficult unless soil samples are collected at the same time each year; for example, in the summer after harvest. Soil pH increases as

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Figure 7.—Apply lime when soil pH is less than 5.5. Lime is best applied preplant so that it can be incorporated into the soil.

Table 1.—SMP buffer lime requirement for tall fescue.

SMP buffer	Amount of 100-score lime needed to raise pH of surface 6 inches of soil to the following pH (t/a)[1]	
	5.6	6.0
4.8 to 5.0	6 to 5[2]	8 to 7[2]
5.1 to 5.3	5 to 4	7 to 6
5.4 to 5.6	4 to 3	6 to 4
5.7 to 5.9	3 to 2	4 to 3
6.0 to 6.2	2 to 1	3 to 2
6.3 to 6.5	0	2 to 1
6.6	0	1

[1]Rates are based on 100-score lime. The combination of calcium carbonate equivalent, moisture, and fineness determines lime score. Lime score is legally required for all materials marketed as "liming materials" in Oregon. Lime application rates should be adjusted for score. For more information about lime score and liming materials, see *Applying Lime to Raise Soil pH for Crop Production (Western Oregon),* EM 9057 (see "For More Information," page 19).

[2]The higher lime rate is required for the lower buffer test reading.

Plant growth regulators

Under growing conditions that include high N availability in spring, the stem cannot support the weight of the developing inflorescence and seed. As a result, the tiller and inflorescence lodge, or fall to the ground. Lodging affects pollination and seed development, so seed yield is reduced.

Plant growth regulators (PGRs) are widely used as a lodging control agent in grass seed production. Seed yield is increased in tall fescue by application of plant growth regulators such as trinexapac-ethyl (TE) and prohexadione calcium during stem elongation (Chastain, et al., 2014). A combination of recommended rates of spring-applied N and application of a PGR at stem elongation will produce the greatest seed yield in most years. Addition of spring-applied N above recommended rates is not needed with PGRs, and it will not increase yield.

soil is wetted with fall and winter rain. It is highest at the wettest time of the year, February or March.

This natural seasonal fluctuation is caused by an accumulation of soluble salts as the soil dries (reducing soil pH) and flushing of salts with winter rainfall (raising soil pH). Fertilizer application can magnify this effect if followed by a dry spring or prolonged dry summer. Since fertilizers are salts, fertilizer addition followed by an especially dry spring or summer increases soluble salts. The result is low soil pH (below 5.3) and a relatively high SMP buffer value (above 6.2). This situation is temporary, however, and soil pH will increase as autumn rainfall leaches the salts.

Where fertilizers have not been recently applied, sandy soils sometimes have low pH and high SMP buffer values. In such cases, an application of 1 to 2 t lime/a should be adequate to neutralize soil acidity.

For more information about problems caused by soil acidity and details about lime application, see *Soil Acidity in Oregon*, EM 9061, and *Applying Lime to Raise Soil pH for Crop Production (Western Oregon)*, EM 9057 (see "For More Information").

Calcium (Ca) and magnesium (Mg) usually exist in the soil in adequate quantities when soil pH is above 5.5. *Where Ca is below 5 meq/100 g soil (1,000 ppm) and soil pH is above 5.0, apply 1 t lime/a.*

When soil requires lime (Table 1, page 6) and soil test Mg is less than 0.5 meq/100 g soil (60 ppm), substitute 1 t dolomite/a for 1 t of the lime requirement. Dolomite and lime have about the same capability to neutralize soil acidity and increase soil pH, but dolomite will also provide Mg. An alternative to dolomite is to broadcast 30 lb Mg/a in addition to lime. Compare material cost before choosing a Mg source.

Nitrogen (N)

Nitrogen fertilizer application recommendations in this guide are in addition to the N supplied by the soil. Soil typically supplies 50 to 100 lb N/a annually, depending on soil type and stand age. Soil N supply usually is highest after establishment, about 100 lb/a for the first 2 years, decreasing to about 50 lb/a in subsequent years.

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Figure 8.—Apply 20 to 40 lb N/a for either a fall or spring seeding of tall fescue.

New seeding

Tall fescue can be established in spring or fall. Crop rotation history and irrigation availability are the primary deciding factors for when to seed.

Irrigation is sometimes used following spring planting to enhance growth and development during the dry summer months. The potential to irrigate a spring-planted crop also allows for the use of tillage and herbicides to control volunteer grass and broadleaf weeds.

Fall-planted tall fescue stands usually follow another grass crop, wheat, clover, or meadowfoam and are sometimes carbon seeded. Irrigation of fall-sown stands is helpful to ensure adequate vegetative growth to survive the winter. Volunteer grass and broadleaf weed competition is often greater in fall-planted, nonirrigated tall fescue stands.

Apply 20 to 40 lb N/a for either a spring or fall seeding (Figure 8). The application can be broadcast preplant or added to the banded charcoal slurry at planting. If N is subsurface banded at planting, at least 1 inch of soil should separate the seed from the fertilizer so the fertilizer does not delay crop emergence.

Established stands

Both fall application (before vernalization) and spring application (after vernalization) are recommended for tall fescue seed production. Postharvest residue management does not affect

the need for N fertilization. Both the amount of N immobilized by straw in a first-year stand and the N available from decomposition in a third-year stand are small (0 to 20 lb/a). Thus, tall fescue fields have the same N requirement, regardless of whether straw is removed or chopped back.

Spring application

Spring N application commonly increases seed yield by 300 to 900 lb/a compared to no spring N application. Maximum tall fescue seed yield is produced with at least 100 lb N/a in the above-ground portion of the plant at harvest (Figure 9). This amount of N is supplied by the soil and through spring fertilizer application. The increase in yield and N shown in Figure 9 is similar to the line representing increasing seed yield with spring N application in Figure 10.

Spring N rate. Prediction of spring N rate from a soil test, such as that used for soft white winter wheat in western Oregon or for perennial ryegrass seed production in New Zealand, is not currently possible in Oregon. More information is found in Appendix A, "Inability of the Nmin Soil Test to Predict Spring N Rate for Tall Fescue" (page 24).

To adequately supply N for tall fescue seed production, apply 100 to 140 lb N/a in the spring.
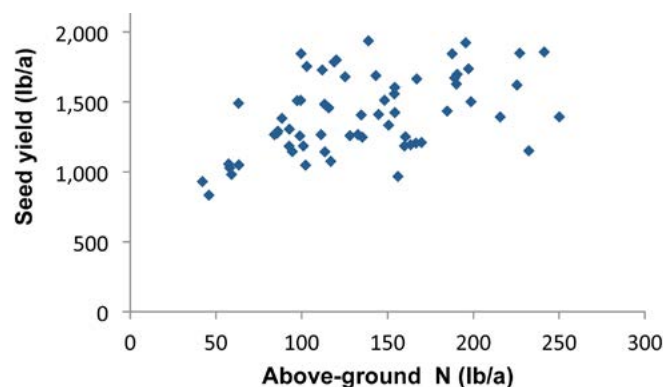

Figure 9.—Tall fescue seed yield increases as available N increases until the plant accumulates approximately 100 lb N/a in the above-ground biomass. Figure by John Hart.

This spring N rate recommendation is made assuming that 30 to 40 lb N/a was applied in the fall (see "Fall application," page 9).

Research in grower fields supports the recommended spring N rate of 100 to 140 lb N/a (Figure 10). In research from 1998 to 2005, spring N rates below 100 lb/a produced top seed yields in 10 of 13 situations. None of the sites receiving fall N required more than 135 lb N/a in the spring to produce maximum economic seed yield.

Nitrogen rate varies from field to field, but is relatively consistent from year to year within the same field. Southern Willamette Valley fields generally require less N than well-drained, irrigated fields in other areas of western Oregon. Our assumption is that poorly drained soils with more than 5 percent organic matter supply more N than well-drained soils with lower organic matter. Therefore, use lower N rates for poorly drained soils.

Timing of spring application. Tall fescue begins growth earlier in the spring than other grass species. Forage-type perennial ryegrass begins spring growth after accumulation of 200 GDD, typically in mid-February. Turf-type tall fescue normally begins growth 3 to 7 days earlier than forage type perennial ryegrass, while forage-type tall fescue begins growth 6 to 12 days earlier than forage-type perennial ryegrass (Figure 11).
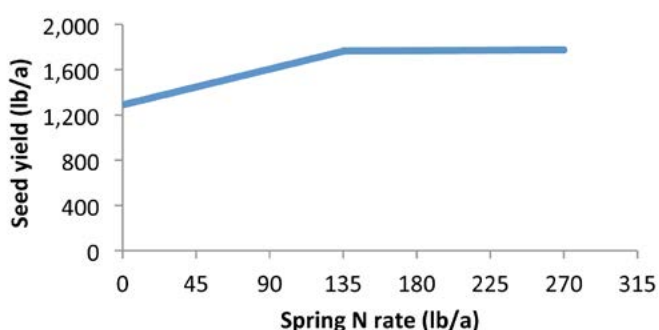

Figure 10.—Average tall fescue seed yield from three sites for 3 years (1998 to 2000) increased approximately 500 lb/a as spring N rate increased to 135 lb/a. Additional spring N did not increase seed yield. Data from Young, Mellbye, et al. (2003); figure by John Hart.
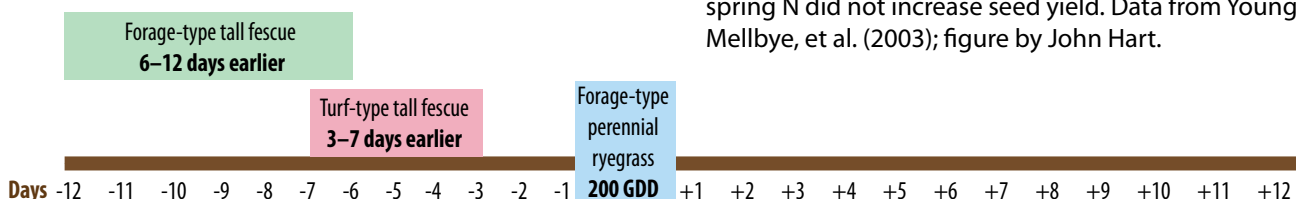

Figure 11.—Relative initiation of growth by forage and turf-type tall fescue compared to forage-type perennial ryegrass. Figure by Teresa Welch.

The peak N uptake, or daily use rate, by tall fescue is highest in late March to early April (Figure 12). In contrast, peak N uptake for perennial ryegrass occurs in mid-April. Tall fescue has accumulated its season total for N by the end of May, while perennial ryegrass continues to use N into June (Figure 13).

Thus, N should be applied earlier to tall fescue than to perennial ryegrass. Begin spring N applications during the last week of January or first week of February.

Although not essential for optimum seed yield, a split spring N application is recommended. Split applications provide greater uniformity and ease of management, accommodate crop uptake, and provide flexibility in avoiding unfavorable weather conditions. Split applications require you to match N supply and crop demand. Apply most of the N (75 to 100 lb/a) by mid-March. The final N application should occur by the end of the first week of April.

Do not apply N to fields with standing water. Nitrogen applied when soils are saturated and plants are yellow will not promote growth.

Fall application

Fall N is required for tall fescue stands. Fall N is supplied from the soil and from fertilizer N application, but measurements are not available to determine the contribution of each source.

Apply 30 to 40 lb N/a in early October. Higher rates of fall N (above 40 lb/a) are not advantageous when spring N is adequate (100 to 140 lb/a).

In grower fields, a 40 lb/a fall N application on tall fescue grown for seed often produces a 100 to 300 lb/a seed yield increase. In OSU on-farm field tests, fall N increased seed yield by an average of 170 lb/a compared to no fall N.

Sometimes, fall N application does not increase tall fescue seed yield. In this situation, either the soil supplies adequate N, some spring N fertilizer remains in the soil, or a combination of these possibilities occurred. (See the sidebar "Interaction between fall- and spring-applied N," page 10, for more information.)

Fall N application serves two purposes. First, it provides N for both fall and spring growth.

Second, it promotes vegetative tiller development so that tillers are sufficiently mature to be vernalized over winter. Seed yield increases as fertile tiller density increases (Figure 14).

Tall fescue fertile tiller number, potential, and actual seed yield are strongly influenced by fall N availability. Other yield components
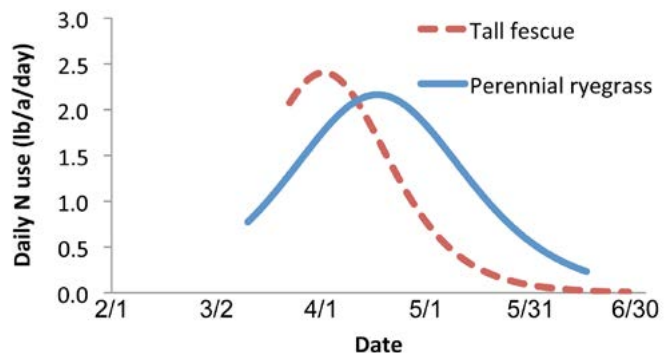
Figure 12.—Peak daily N accumulation of above-ground biomass occurs earlier in tall fescue than in perennial ryegrass when both are grown for seed in western Oregon. Figure by John Hart.
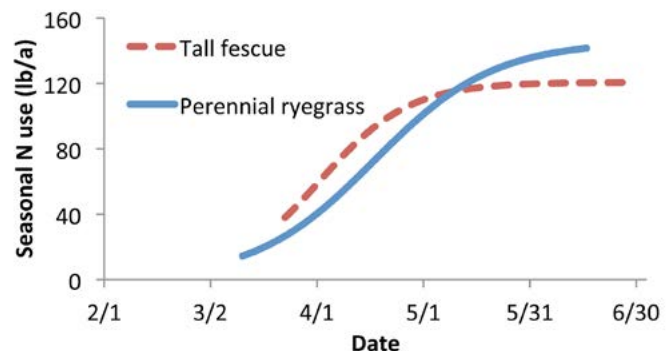

Figure 13.—Tall fescue N accumulation is complete by the end of April, while perennial ryegrass continues to use N into June. This figure shows N in above-ground biomass. Figure by John Hart.
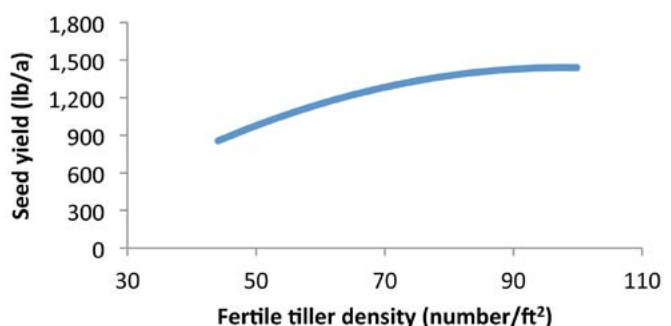

Figure 14.—Tall fescue seed yield increase with increasing fertile tiller density. Data from Young, et al. (2002); figure by Tom Chastain.

Interaction between fall- and spring-applied N

Tall fescue receives fall N from fertilizer application and from the soil. When soil N level is moderate, the application of 40 lb N/a in the fall not only supports tiller production, but also supplies N for growth later in winter.

Some of the soil N available in the fall is unused N from a spring application. The average postharvest soil nitrate-N in tall fescue fields was approximately twice the amount measured in perennial ryegrass seed fields. It also varied annually during a 3-year period during which identical N treatments were applied. Thus, spring N rates exceeding 160 lb/a in tall fescue seed fields likely will satisfy the crop's spring growth needs and leave some N for fall use. (See Appendix B, "Tall Fescue Efficiently Uses N," page 27.)

The fall soil N supply is unknown and not reliably measurable, thus raising the possibility of increasing the spring N rate and forgoing fall N application. This approach gives rise to three possible scenarios.

Scenario 1: When soil N is sufficient in the fall to meet a minimum fall N need for tall fescue seed production, fall N application can be replaced by an increased spring N rate. Figure 15 represents this scenario. When no fall N was applied, seed yield was higher with the application of 180 lb N/a in the spring compared to 140 lb N/a. The increased spring N rate did not significantly increase seed yield, however, when 40 or 80 lb N/a was applied in the fall, indicating that the additional spring N was able to replace fall N application.
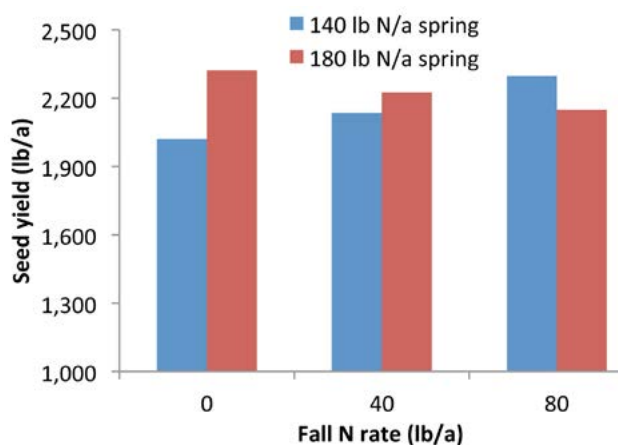

Figure 15.—When no fall N was applied, a higher rate of spring N increased seed yield. The increase in seed yield with additional spring N was absent when fall N was applied. Data from Young, et al. (2004); figure by John Hart.

Scenario 2: Seed yield might not increase when no fall N is applied and the normal fall N rate (40 lb N/a) is added to the spring N application (Figure 16). The data in Figure 16 were collected in a grower field where no fall N had been applied for 2 years. Seed yield did not increase when the recommended spring N rate (100 to 140 lb N/a) was exceeded.
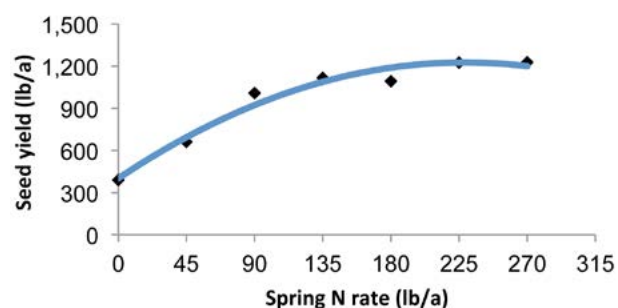

Figure 16.—'Duster' tall fescue seed yield with increased spring N rate after no fall N was applied for 2 years. Data from Young, et al. (2000); figure by John Hart.

Scenario 3: In some cases, an increased spring N rate, followed by no fall N application, produces a lower yield than application of the recommended spring N rate followed by fall N application (Figure 17).
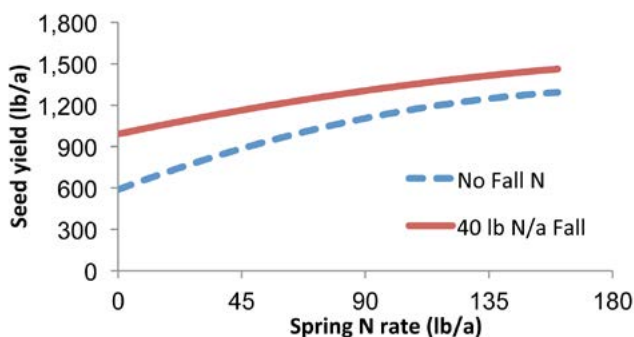

Figure 17.—'Velocity' tall fescue seed yield with increased spring N rate and 0 or 40 lb N/a in the fall. Data from Young, et al. (2002); figure by John Hart.

Conclusion

No soil or tissue measurement is available to determine the fall N status of a tall fescue field. Furthermore, the result of substituting additional spring N for a regular fall N application is unpredictable. *Thus, we recommend application of 100 to 140 lb N/a in the spring and 40 lb N/a in the fall.*

(spikelet number, floret number, and mean seed weight) do not significantly increase from application of fall N (Figure 18). The site represented in Figure 18 was quite low in available N and was chosen to demonstrate the need for fall N in tall fescue seed production. Similar results are not expected in grower fields, as N supply is usually higher than that at the site represented in Figure 18.

For information on choosing an N source and application method, see the sidebar "Source of N and method of application."

Phosphorus (P)

Plants require much less P than N or K. Tissue P concentration of tall fescue in vegetative development (jointing through flag leaf emergence) is usually 0.2 to 0.4 percent. About 25 lb P/a is found in physiologically mature tall fescue plants, which is less than one-fifth the amount of K at the same stage of maturity.

Like other crops, tall fescue moves P into the leaves, where it is incorporated into enzymes used for the transfer of energy produced by photosynthesis. Phosphorus moves from old (lower) leaves to new (upper) leaves. Therefore,
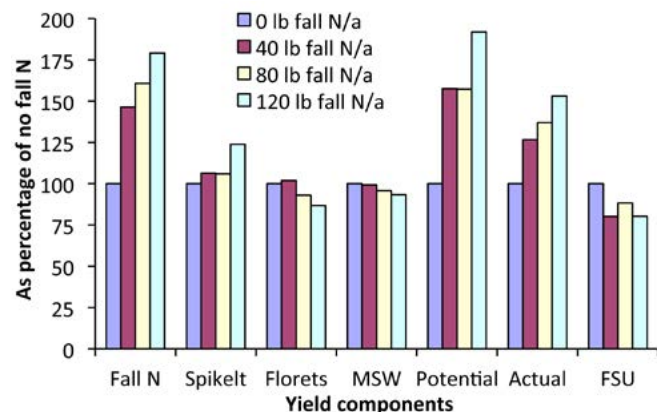

Figure 18.—Yield components and seed yield for 'Velocity' tall fescue grown on a site with very low N supply:
(1) F Tiller = fertile tiller (panicle) number/ft² expressed as a percentage of the 0 N treatment; (2) Spiknum = spikelet number per panicle expressed as a percentage of the 0 N treatment; (3) Florets = florets/spikelet expressed as a percentage of the 0 N treatment; (4) MSW = mean seed weight; (5) Potential = potential seed number; (6) Actual = actual number of seeds produced per unit area expressed as a percentage of the 0 N treatment; and (7) FSU = actual seed per potential seed (floret number per unit area). Data from Young, et al. (2002); figure by Tom Silberstein.

lower leaves become discolored when P is deficient.

Need for P fertilization

Phosphorus deficiency in western Oregon field and vegetable crop production is rare. Soil test available P values are commonly above 50 ppm, especially in the central and northern Willamette

Source of N and method of application

Nitrogen for tall fescue seed production is top-dressed as urea (46-0-0) or as a physical mix of urea and ammonium sulfate (urea-sul, 40-0-0-6). Another relatively common N source is urea-ammonium nitrate solution (Solution 32). No difference in N availability exists among these sources for tall fescue seed production.

Use of a nitrification inhibitor, polymer coating, or urease inhibitor is not recommended as a standard practice, since no evidence exists of their benefit in western Oregon tall fescue production. Polymer-coated urea does not produce a predictable or sufficient yield increase to justify the cost.

In New Zealand, urease inhibitors used to reduce volatile N loss produced a 7 percent seed yield increase. These materials have not been evaluated in western Oregon grass seed production systems. When tall fescue seed fields top-dressed with spring N fertilizer receive more than ¼ to ½ inch of rain within 48 hours of application, urease inhibitors should not be necessary. See Appendix C, "Comparison of Urea and a Mixture of Polymer-coated Urea and Uncoated Urea for Tall Fescue Seed Production" (page 29).

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Figure 19.—No advantage has been found from the use of polymer-coated urea in western Oregon tall fescue seed production. Photo shows a blend of polymer-coated urea and other nutrients.

Valley and Tualatin Valley, where rotations with legume and vegetable crops are common. Phosphorus fertilizer is not needed on established tall fescue stands when soil test P is above 25 ppm.

On the other hand, soil test P can be below 25 ppm in several situations, such as fields primarily used for annual ryegrass seed production, "black" clay soils in the Tualatin and southern Willamette valleys, and "hill" soils adjacent to the Tualatin and Willamette valleys, such as the Silverton Hills and foothills of western Polk County.

Use the Bray method to measure soil test P available to the plant. For both new and established stands, use Table 2 to determine the need for P fertilizer and the rate of P_2O_5 to apply. *Application rates in Table 2 supply adequate P for a tall fescue seed crop.*

Table 2.—Phosphorus fertilizer application rates for tall fescue.

Soil test or plant-available P (ppm)[1]	Apply this amount of P_2O_5	
	New seeding (lb/a)	Established stand (lb/a)
0 to 15	40 to 60	30 to 40
16 to 25	30 to 40	0 to 30
Above 25	0	0

[1]Application rates based on a soil test using the Bray method for determination of plant-available P.

Predictable yield increase from P application to an established stand is not measured unless soil test P is less than 15 ppm.

The need for P when soil test P is between 15 and 25 ppm varies with stand age, previous P application, and grower perspective. For example, if a tall fescue seed field received top-dress P the previous 2 years and is in its final year of production, it likely will not benefit from P application. In contrast, seed yield of a first-year field might increase following P application when soil test P is below 25 ppm.

A yield increase is rare when soil test P is greater than 25 ppm. In this case, any yield increase that occurs following P application usually is the result of correcting problems such as root disease or another factor limiting plant root growth.

For established fields with soil test P between 25 and 50 ppm, a maintenance or replacement application of P is sometimes used to replace the amount removed with the crop. This application can be made in spring or fall. Most P remains in the straw and is slowly recycled when straw is chopped. Since very little P is removed in seed, consider making a replacement application only if straw is baled. Even with baling, however, the economics of this approach are difficult to justify.

As shown in Figure 21, seed yield was not increased by P fertilization when soil test P was 60 ppm.

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Figure 20.—In mature stands, the need for P depends not only on soil test P, but also on stand age, previous P application, and grower perspective.
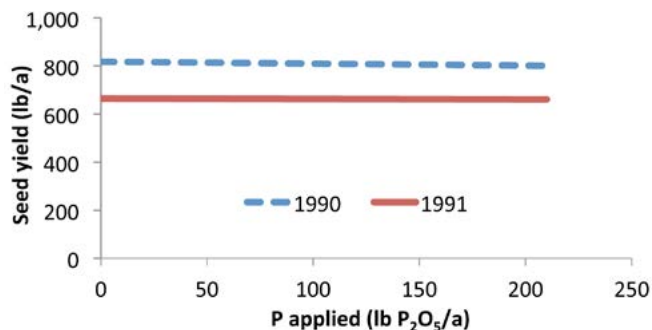

Figure 21.—The influence of top-dress P application rate on tall fescue seed yield for 2 years. Soil test P was 60 ppm, indicating no need for additional P. Figure by John Hart.

Effects of P fertilizer application

Tall fescue, perennial ryegrass, wheat, and other field crops are usually darker green within a week of spring N application. In contrast, changes in plant growth, color, or nutrient accumulation are not readily apparent after top-dressing P on perennial grass seed crops.

Furthermore, P in the above-ground biomass increased only when high rates of P were used or when tissue was sampled more than a year after application (Figure 22). After the first year (1989), only the highest application rate (210 lb P_2O_5/a) increased the amount of P in above-ground biomass. After a second year, P accumulation significantly increased following application of either 140 or 210 lb P_2O_5/a (compared to no applied P or 70 lb P_2O_5/a). These observations illustrate that top-dress P applications do not result in rapid changes in plant P levels, as would be expected from a top-dress N application.

For information about the effect of P application on plant-available P in the soil, see the sidebar "Increasing soil test P."

P fertilizer application method and timing

Phosphorus mobility in soil is limited, moving less than 0.015 inch/day. Soil immobility creates high soil test concentration of P in the surface 2 inches of soil after top-dressing.
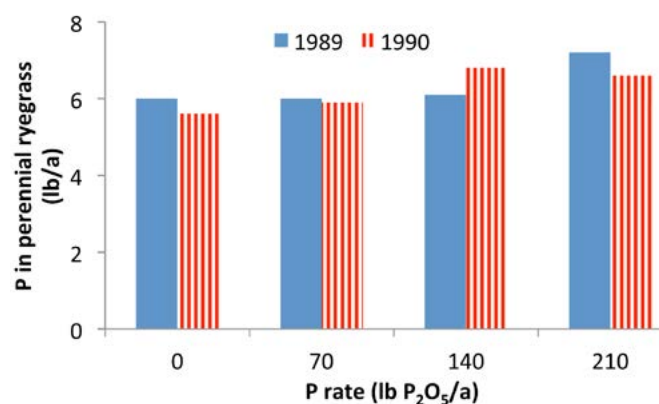

Figure 22.—The influence of top-dress P application rate on above-ground P in perennial ryegrass biomass,1989 and 1990. A single top-dress P application was made in the fall of 1988. Data from Horneck (1995); figure by John Hart.

Increasing soil test P

Soil test P is not easily increased, especially in several dark-colored alluvial soils high in clay content, such as Wapato and Bashaw soils. To increase soil test P in these soils, repeated applications of large quantities of P are needed.

Three categories of P are found in soil: (1) soluble (in soil solution) and immediately available for use by plants, (2) in soil (not in solution) and available for plant utilization, and (3) unavailable for plant use (mineral or precipitated material).

Tall fescue and other plants obtain P from the soil solution. The Bray soil test measures soluble P and P that will be available during the growing season.

Fertilizer P is relatively soluble when applied. As it reacts with soil, its solubility decreases, and eventually it becomes unavailable for plant growth, as shown below.

Soluble P ↔ Available in soil → Not available for plant use

Unfortunately, P concentration in soil solution is very low. In the top foot of two western Oregon grass seed fields, between 85 and 150 grams (3 to 5 oz) of inorganic or plant-available P was in solution when soil test P was above 20 ppm. A rapidly growing grass seed crop requires more than 200 grams or almost 8 oz of P/a each day. To adequately supply a tall fescue crop, the soil solution must be replenished multiple times daily.

Fortunately, solution P is continually replenished from P in the soil, as shown above by the double-headed arrow. Also, soil test P decreases slowly from plant use, less than 1 ppm/year for the silt loam, clay loam, and silty clay loam soils typically used for grass seed production in western Oregon. Thus, soil with more than 35 ppm soil test P can adequately supply P to grass seed crops for several years.

Increases in soil test P require considerably more P than needed to meet crop requirement. To increase soil test P 1 ppm in the surface inch of soil in western Oregon, between 25 and 50 lb P_2O_5/a is required. An increase in soil test P after top-dress P fertilizer application can be measured in the surface 2 to 3 inches of soil in 3 years, but if the same rate is mixed into the soil with tillage, you will not measure an increase in soil test P for more than 3 years, and possibly as long as a decade.

Increasing soil test P above 20 ppm does not increase the amount of P in soil solution or the P supply available to a tall fescue seed crop. Soil water content (which is controlled by soil textural class—sand, silt, and clay) and organic matter content are key factors in determining the amount of P available to the crop.

At planting, a band application of P is an efficient method of delivering P to a tall fescue crop. However, when other nutrients such as K are banded at planting, at least 1 inch of soil should separate the seed from fertilizer, as placing fertilizer with seed delays germination and emergence.

When P is deficient in an established stand, fall application is recommended. If P is sufficient and a maintanence application is being applied, method and timing do not matter (Figure 23).

Potassium (K)

Compared to other nutrients, K is required by grass plants in large amounts. Even so, physiologically mature tall fescue plants usually contain less than 2.5 percent K. Although 2.5 percent is a small percentage of total biomass, it is much more than needed to produce top seed yields.

Potassium is concentrated in straw, with only a small percentage being found in the seed. Baling straw removes substantial amounts of K (Figure 24). Thus, more K must be added when straw is baled rather than chopped.

Straw K concentration changes little once soil test K exceeds 150 ppm (Figure 25). Thus, K plant uptake is governed by the amount of biomass produced.

New seeding

Meeting a tall fescue seed crop's K needs during an entire rotation begins with soil sampling and analysis before planting. When K soil test values are sufficient at planting, and little or no straw will be removed after harvest, K may be sufficient for the stand life.

When K is needed, application before or at planting is an efficient method of supplying potash (K_2O fertilizer) to a tall fescue seed crop. Use Table 3 to determine the K_2O application rate.

When banding K at planting, at least 1 inch of soil should separate the seed from fertilizer. Do not exceed 30 to 40 lb K_2O/a when banding K with seed. To minimize salt injury, a banded application of N plus K (as K_2O) should not exceed 90 lb/a, combined.
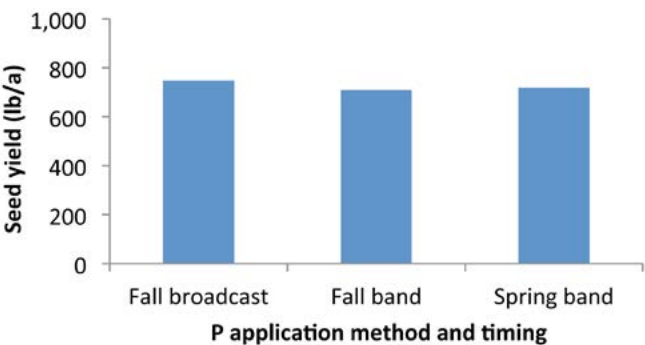

Figure 23.—Two-year average tall fescue seed yield from top-dressed P. Data from Horneck and Hart (1991); figure by John Hart.

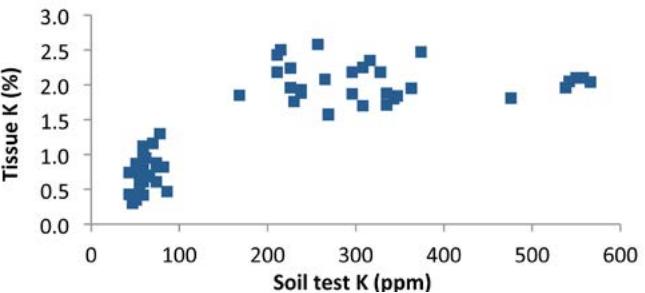Figure 24.—Baling straw removes K from the field.

Figure 25.—Tall fescue tissue K concentration as a function of soil test K. Tissue K increases as soil test K increases to 150 ppm, but does not increase with higher soil test K levels. Data from Horneck (1995); figure by John Hart.

Table 3.—Potassium fertilizer application rates for tall fescue.

Soil test K (ppm)[1,2]	New seeding (lb/a)	Apply this amount of K_2O	
		Established stand	
		Straw management	
		Bale (lb/a)	Chop (lb/a)
0 to 50	200 to 250	150 to 200	100 to 150
50 to 100	100 to 200	75 to 150	50 to 100
100 to 150	30 to 40	0 to 75	0 to 50
Above 150	0	0	0

[1]Ammonium acetate extractable.

[2]Application rates based on a soil sample collected from a 6- to 7-inch depth.

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Established stands

Usually, recommended K application rates exceed the amount that can be banded safely at planting. Therefore, established tall fescue seed fields are commonly top-dressed with potassium chloride (KCl; analysis 0-0-60), also known as muriate of potash. This practice adds K to the soil surface, similar to the result of chopping the full straw load.

Determine the K application rate from Table 3 (page 14) based on a soil test analysis of a sample collected from the surface 6 to 7 inches. When soil test K is above 150 ppm, the soil will adequately supply K to the crop, and no K application is needed. *When soil test K is between 100 and 150 ppm, K application is not critical if straw is left on the field. However, maintenance applications are usually necessary when straw is baled and soil test levels fall below 150 ppm.* Even where straw is baled, however, K application is not critical, especially if soil test K is close to 150 ppm and the crop is in its final year.

Potassium application on established stands can occur in the fall or spring. Fall application is recommended if soil test K is below 100 ppm. A fall K application allows roots to contact top-dressed K as the crop begins to grow in early February. Adequate moisture during early spring allows plants to readily use K in the top 1 to 2 inches of soil. Thus, the rate of K assimilation is greatest (3 to 4 lb/a/day) before rapid spring growth occurs during the first half of April (Figure 26). Applying K in the fall makes it available during this period of rapid K uptake.

Spring applications of KCl on perennial ryegrass have sometimes produced a seed yield increase (typically less than 10 percent) from the Cl rather than from the K. However, research with tall fescue seed crops has not shown a similar response. When soil test K is above 100 ppm, an increase in tall fescue seed yield from a spring application of K is unpredictable and occurs infrequently. For more information on this topic, see Appendix D, "Chloride in Tall Fescue Seed Production" (page 31).

Additional information about soil test K and grass seed production is available in *Postharvest Residue Management for Grass Seed Production in Western Oregon* (EM 9051) and in Appendix E, "Substantiating K Requirement for Tall Fescue Seed Production" (page 33).
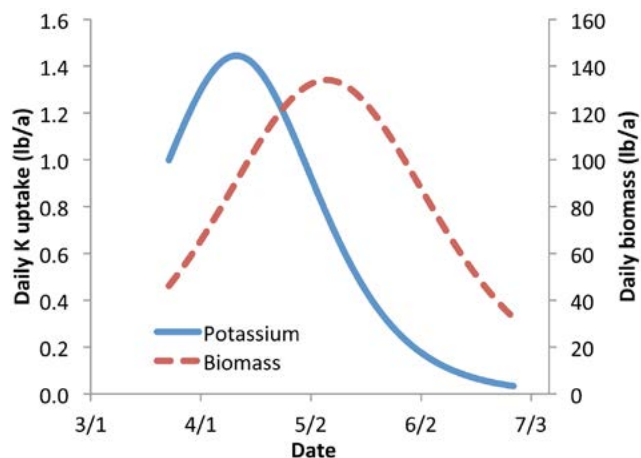
See also the sidebar "Potassium and plant water use."

Figure 26.—Daily total above-ground biomass (seed plus straw) and K accumulation for tall fescue grown for seed in western Oregon. The period of most rapid K accumulation occurs before the period of peak growth. (Seasonal biomass values are higher than the sum of grower seed and straw harvest, as all above-ground biomass, including crowns, was carefully clipped in small plots.) Data from Qureshi (1995); figure by John Hart.

Potassium and plant water use

As part of the plant's regulation of water, tall fescue obtains K through the roots and moves it to the leaves. When a plant uses K for water balance, it accumulates much more K than it needs for seed production. The term "luxury consumption" is sometimes used to describe plant uptake beyond the nutritional requirement.

To be used by plants as part of the water balance mechanism, K must be easily moved from one tissue to another. It also must be easily removed from dry plant tissue by irrigation water or rain. This aspect of K movement allows rapid recycling of K when straw residue is left on the field after harvest.

Sulfur (S)

In addition to N, K, and low soil pH, S is the element most likely to limit tall fescue seed yield in western Oregon. Seed yield increase from S application is site- and year-specific.

No soil test adequately predicts soil S supply; therefore, regular S application is recommended. *For stand establishment, band 15 to 25 lb S/a at planting. For established stands, a spring S application of 15 to 25 lb S/a is preferred, but S also can be applied in the fall. An alternative is to apply 30 to 50 lb S/a every other year.*

The recommended application rate provides ample S to replace S removed with seed and straw. A typical yield (1,400 lb seed/a) contains about 1 lb S/a, and an average straw yield (5,000 lb/a) contains about 12 lb S/a. Thus, S removal with seed and straw is approximately 13 lb/a.

Additional S, about 7 lb/a, resides in crowns and straw not removed by baling. An estimated 10 lb S/a is contained in roots, making the total amount of S in a tall fescue seed crop 30 lb/a.

Supply S in the sulfate (SO_4-S) form, not as elemental S (Figure 27). Use of elemental S, especially in spring S application, is not recommended, as it must be microbially converted to SO_4-S to be plant available. See Appendix F, "Sulfur in Western Oregon Soils" (page 34) for more information.

Tall fescue S accumulation begins gradually, with about 1 lb S/a present in the above-ground biomass by mid-March (Figure 28). Accumulation increases linearly throughout the season, reaching 20 to 25 lb/a at harvest. This amount is contained in approximately 5 tons of biomass, twice the amount typically removed by baling straw.

Daily S accumulation parallels biomass accumulation. Both begin slowly; 0.2 lb S/a is used daily in mid-March, but by early May daily use increases to almost 0.6 lb S/a (Figure 29). In contrast, N and K use substantially precede biomass accumulation. Sulfur use differs between tall fescue and perennial ryegrass (see the sidebar "Sulfur use in tall fescue and perennial ryegrass," page 17).

Figure 27.—Urea ammonium sulfate, 40-0-0-6, is a popular source of N and S.

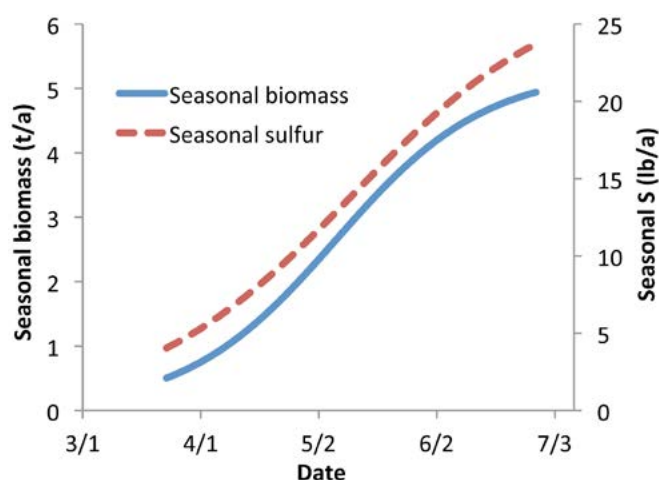Nicole Anderson, © Oregon State University

Figure 28.—Annual total above-ground biomass (seed plus straw) and S accumulation for tall fescue grown for seed in western Oregon. (Seasonal biomass values are higher than the sum of grower seed and straw at harvest, as all above-ground biomass, including crowns, was carefully clipped in small plots). Data from Qureshi (1995); figure by John Hart.
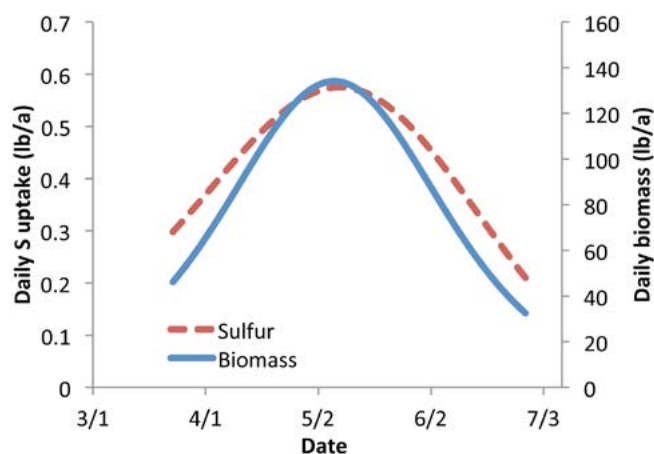

Figure 29.—Daily total above-ground biomass (seed plus straw) and S accumulation for tall fescue grown for seed in western Oregon. Data from Qureshi (1995); figure by John Hart.

Little S is used in late winter and early spring, so applying S with spring N is recommended (Figure 30). By applying S at this time, S is available for crop use during rapid growth in April and May.

As the plant grows, tall fescue tissue S decreases rapidly from 0.25 to 0.35 percent in late March to 0.15 to 0.20 percent at anthesis (the period when florets are open and receptive to pollen). Therefore, using S concentration for determination of S sufficiency is difficult. An alternative approach is to use the N:S ratio in plant tissue for diagnostic purposes. See the sidebar "Early season diagnosis of S deficiency" (page 18) for more information.

Figure 30.—For established stands, apply S in the spring with N.

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Sulfur use in tall fescue and perennial ryegrass

Tall fescue use of S differs substantially from perennial ryegrass use of S. The maximum daily accumulation rate of more than 0.5 lb/a for tall fescue is about three times the rate for perennial ryegrass (Figure 31). In addition, maximum tall fescue S use occurs 2 weeks later than in perennial ryegrass—early May for tall fescue and late April for perennial ryegrass.
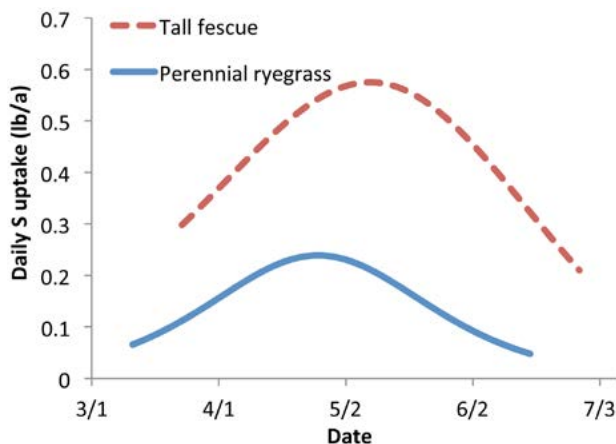
Tall fescue S accumulation not only occurs at a higher daily rate compared to perennial ryegrass, but it also continues for a longer time. The combination of these factors allows tall fescue to accumulate about one-third more S than perennial ryegrass (Figure 32).

The late-season utilization of S by tall fescue is partially attributed to plant growth. This continued growth is noted by many growers as "staying green" through harvest.

Figure 31.—Daily total above-ground S accumulation for tall fescue and perennial ryegrass grown for seed in western Oregon. Tall fescue data from Qureshi (1995) and perennial ryegrass data from Horneck and Hart (1989); figure by John Hart.
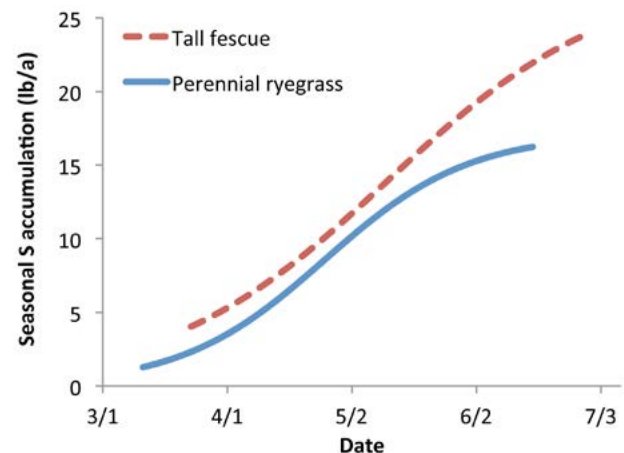

Figure 32.—Annual total above-ground S accumulation for tall fescue and perennial ryegrass grown for seed in western Oregon. Tall fescue data from Qureshi (1995) and perennial ryegrass data from Horneck and Hart (1989); figure by John Hart.

Early season diagnosis of S deficiency

Growers often assume that pale green or yellow leaves are a sign of nutrient deficiency, specifically N or S. However, nutrient deficiencies are not the only cause of pale or yellow leaves. They can be the result of numerous problems or conditions.

Sulfur is routinely applied to most crops in western Oregon. Therefore, S deficiency in a western Oregon tall fescue seed crop is uncommon.

Sulfur-deficient plants appear very pale, since the new growth is light colored and often hides the darker green lower leaves. When looking for S deficiency, examine plants closely, as the view from a vehicle or even walking through a field can deceive you into thinking the entire plant is pale.

Early season N deficiency is also uncommon. If present, it is expressed by yellowing of older leaves as N is moved to new tissue.

Plant analysis can be used to rapidly determine whether yellow leaves might be caused by lack of S or another problem. This approach differs from the standard evaluation of tissue concentration of a single element or nutrient. For evaluation of plant S status, the ratio of tissue N and S is used.

The amounts of N and S in protein are the basis for using the N:S ratio to determine S sufficiency. Using a ratio of two elements rather than the concentration of S alone eliminates the difficulty in recognizing when a decrease in tissue concentration is caused by rapid growth.

To evaluate early season S deficiency in tall fescue, collect leaves and stems from the entire above-ground portion of the plant. Have the sample analyzed for N and S. Before calculating an N:S ratio, examine the results to eliminate the possibility that both N and S might be deficient. The S concentration should be greater than 0.2 percent, and the N concentration higher than 3 percent.

To calculate the N:S ratio in tissue, divide the N concentration by the S concentration (%N ÷ %S). For example, tissue with 3 percent N and 0.2 percent S has an N:S ratio of 15 (3 ÷ 0.2 = 15). To evaluate S sufficiency, compare the N:S ratio you calculated with the values in Table 4.

Table 4.—Evaluation of N:S ratio for perennial ryegrass.

N:S ratio	Evaluation	Comments
Less than 10:1	S is adequate.	N should be higher than 3%; otherwise it might be limiting growth.
Between 10:1 and 15:1	S may or may not be limiting.	—
Greater than 15:1	S is deficient.	Tissue S below 0.2 percent is likely.

Micronutrients (B, Cl, Cu, Mn, Fe, Zn)

Seed yield increases from micronutrient application in tall fescue seed production have not been documented in western Oregon. Soil test boron (B) levels are usually low (less than 0.5 ppm), and both tissue and soil test B increase when B is applied. A single application of 1 lb B/a will increase tissue B for more than a year. However, seed yield increases from B application have not been measured for tall fescue seed production.

Zinc (Zn) is adequate for grass seed production when the DTPA soil test value is above 0.6 ppm. If the soil test value is below 0.6 ppm, apply 1 to 5 lb Zn/a on a trial basis.

Additional information about micronutrient application for tall fescue seed production is available in Appendix G, "Micronutrients for Western Oregon Grass Seed Production" (page 37).

For More Information (OSU Extension publications)

Annual Ryegrass Grown for Seed (Western Oregon) Nutrient Management Guide, EM 9086. Revised February 2001. https://ir.library.oregonstate.edu/xmlui/bitstream/handle/1957/44756/em9086.pdf

Applying Lime to Raise Soil pH for Crop Production (Western Oregon), EM 9057. May 2013. http://ir.library.oregonstate.edu/xmlui/bitstream/handle/1957/38531/em9057.pdf

Perennial Ryegrass Grown for Seed (Western Oregon) Nutrient Management Guide, EM 8854-E. November 2013. http://ir.library.oregonstate.edu/xmlui/bitstream/handle/1957/20032/em8854-e.pdf

Postharvest Residue Management for Grass Seed Production in Western Oregon, EM 9051. September 2012. http://ir.library.oregonstate.edu/xmlui/bitstream/handle/1957/33454/em9051.pdf

Soil Acidity in Oregon, EM 9061. http://ir.library.oregonstate.edu/xmlui/bitstream/handle/1957/41199/em9061.pdf

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Acknowledgments

Appendix A. Inability of the Nmin Soil Test to Predict Spring N Rate for Tall Fescue

OSU developed an early season N mineralization soil test measure for wheat growers to refine their spring N rate. New Zealand growers utilize this test to predict N needs in perennial ryegrass seed crops. Oregon grass seed growers desired a similar test for use in western Oregon grass seed production.

To evaluate utility of the Nmin test for estimating spring N requirement of tall fescue grown for seed, 8 tall fescue field-scale trials with nonreplicated N rates of 0, 60, 120, and 180 lb/a were established in 2005. Plots were 20 to 25 ft wide and at least 500 ft long. Table 5 provides site information and soil test N results from 12-inch-deep samples collected in January.

Calibration of the Nmin test is a multistep process. The first step is to relate N availability, as measured by the Nmin test, to N accumulation or "uptake." This step is needed because grass seed yield is related to N uptake. Tall fescue requires 125 to 175 lb N/a to produce optimum yield (Figure 33). Thus, for the Nmin soil test to be of value, it should be related to N uptake.

The relationship between the Nmin soil test and "mineralized N for uptake" is encouraging but weak. Only 20 percent of the change in N uptake is related to the Nmin value. The trend (regression) line for the data shows that each ppm of mineralized N produces about 2 lb N in tall fescue (Figure 34).

If the relationship between the Nmin soil test and N accumulation in tall fescue is correct, we should be able to estimate the N rate needed from the Nmin soil test. This step was made for a different data set—two tall fescue Nmin plots from the previous year (2004).
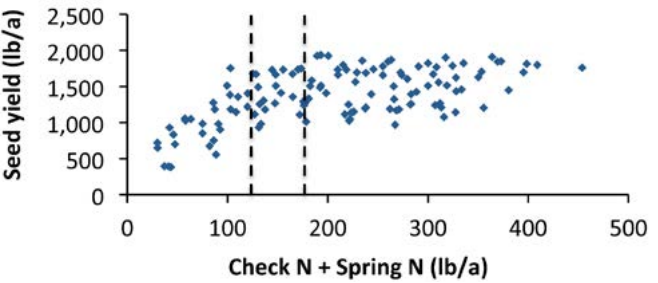

Figure 33.—Relationship between tall fescue seed yield and N supply. Nitrogen supply is the sum of N applied as fertilizer in the spring and N uptake from soil. Optimum yield is achieved with N supply of 125 to 175 lb/a. Figure by John Hart.
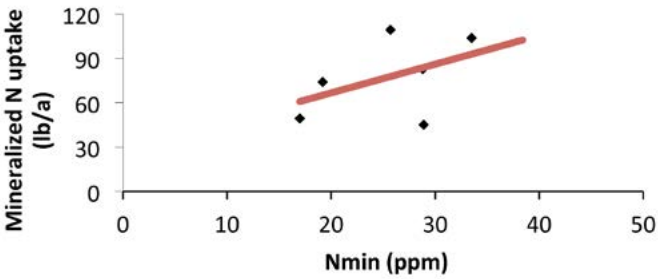

Figure 34.—The relationship between Nmin soil test results (0- to 12-inch depth) in January and tall fescue N estimated to be from mineralized soil N, 2005. Figure by John Hart.

Table 5.—Straw management, soil series, and soil test N results for field sites, 2005.

Location	Stand age (years)	Straw management	Soil series	NO$_3$-N	NH$_4$-N	Nmin
Harrisburg	5	Baled	Malabon-Holcomb	5.0	2.3	38.4
Shedd	3	Full straw	Woodburn	3.4	2.9	17.0
Monroe	3	Baled	Chehalis	3.9	3.6	19.2
Monroe	1	Full straw	Chehalis	5.3	3.8	25.7
Mt. Angel	4	Full straw	Amity	2.0	1.4	33.5
Suver	3	Full straw	Woodburn-Dayton	3.9	4.4	28.9
Rickreall	4	Full straw	Coburg Cove	3.5	6.3	28.8
Dayton	6	Baled	Aloha	9.1	3.1	17.5

Appendix A—*continued*. Inability of the Nmin Soil Test to Predict Spring N Rate for Tall Fescue

In Table 6, the calculated N application rate is the difference between the maximum N requirement (175 lb/a) and the expected available N (based on Nmin soil test results). The optimum N rate is the rate needed to produce maximum economic yield (determined from the incremental addition of N (0, 60, 120, 180 lb/a). As seen in Table 6, the N rate calculation based on the Nmin soil test is not consistent with the N rate needed to produce optimum yield.

The Nmin values from the 2004 plots (Table 6) were not low. We therefore assumed that low Nmin test values were needed for calibration of the procedure. In 2005, the Nmin test values from two tall fescue fields were low, below 20 ppm (Table 7, page 26). However, N uptake from these sites typically was more than 100 lb/a without addition of any N fertilizer. Furthermore, Nmin soil test results were not correlated with N uptake or seed yield.

Conclusion

Use of the Nmin soil test for prediction of spring N rate in tall fescue is not recommended since we do not know the relationship of the test to either N uptake or seed yield. This result is frustrating for Oregon grass seed growers,

Figure 35.—The Nmin test does not adequately predict spring N rate for tall fescue.

especially since New Zealand growers successfully use the Nmin test for predicting spring N fertilizer needs in perennial ryegrass seed production. A comparison of perennial ryegrass seed production in New Zealand and Oregon highlights similarities and differences, but does not provide a definite reason for the differing performance of the Nmin test.

Table 6.—Evaluation of Nmin soil test for tall fescue, 2004.

Site	Available N (lb/a)	Nmin soil test (ppm)	Expected available N (lb/a)	Calculated N application rate (lb/a)	Optimum N application rate (lb/a)
1	39	55	174	0	120
2	16	33	108	67	120

Appendix A—*continued*. Inability of the Nmin Soil Test to Predict Spring N Rate for Tall Fescue

Table 7.—Tall fescue Nmin test value, N uptake, seed yield, tissue N concentration, biomass, and 1,000-seed weight, 2005.

Site	N application rate (lb/a)	Nmin test value (ppm)	N uptake (lb/a)	Seed yield (lb/a)	Tissue N concentration (%)	Biomass (lb/a)	Seed weight (g/1,000)
1	0	24.8	57	1,268	0.81	7,078	2.59
	60	—	66	1,308	0.87	7,597	2.57
	120	—	113	1,503	1.11	10,152	2.58
	180	—	129	1,317	1.33	9,734	2.62
	Grower rate[1]	—	71	1,325	0.81	8,789	2.55
4	0	22.4	72	1,127	0.91	7,398	2.58
	60	—	106	1,401	0.98	10,852	2.57
	120	—	150	1,235	1.18	12,740	2.58
	180	—	191	1,237	1.66	11,513	2.62
	Grower rate	—	117	1,415	1.30	8,972	2.55
8	0	31.0	101	1,144	0.87	11,629	3.23
	60	—	68	1,366	0.87	7,854	3.23
	120	—	131	1,036	1.33	9,840	3.30
	180	—	200	1,218	1.79	11,190	3.34
	Grower rate	—	77	1,395	0.87	8,824	3.25
9	0	19.5	142	2,874	1.23	11,532	2.41
	60	—	244	2,591	1.72	14,190	2.46
	120	—	239	2,786	1.98	12,053	2.54
	180	—	303	2,707	2.04	14,837	2.43
	Grower rate	—	173	3,299	1.38	12,522	2.47
12	0	33.5	116	1,468	0.99	11,704	2.64
	60	—	192	1,570	1.37	14,006	2.53
	120	—	230	1,526	1.58	14,575	2.51
	180	—	222	1,527	1.77	12,527	2.47
	Grower rate		416	1,494	2.37	17,533	2.64
15	0	24.4	75	837	0.97	7,766	2.40
	60	—	121	836	1.32	9,143	2.44
	120	—	92	492	1.17	7,884	2.42
	180	—	175	611	1.68	10,419	2.43
	Grower rate	—	167	1,336	1.56	10,701	2.25
16	0	32.3	118	1,945	0.86	13,715	2.61
	60	—	202	2,117	1.29	15,629	2.49
	120	—	192	2,023	1.39	13,796	2.53
	180	—	217	1,634	1.67	12,966	2.57
	Grower rate	—	164	—	1.24	13,196	2.52
17	0	15.6	190	1,558	1.59	11,970	2.49
	60	—	151	1,493	1.53	9,857	2.52
	120	—	212	1,343	1.94	10,932	2.60
	180	—	179	1,393	1.51	11,850	2.58
	Grower rate	—	169	—	1.48	11,422	—

[1]Grower rate = N application rate by grower in field outside of plot area.

Appendix B. Tall Fescue Efficiently Uses N

Nitrogen (N) is the most limiting nutrient for western Oregon crop production. Most tall fescue seed growers apply slightly more N than recommended by OSU. This practice raises questions about the amount of N remaining after harvest. Nitrogen not used by the crop can be vulnerable to leaching by fall and winter rain.

Postharvest nitrate-N (NO_3-N) was measured in three western Oregon tall fescue seed fields. Samples were collected from the surface to a depth of 3 feet. Average data from two fields showed that even when no spring N fertilizer was applied, a small amount of NO_3-N (about 20 lb/a) was measured following harvest (Figure 36). When N was applied within the recommended spring rate (135 lb N/a), approximately 45 lb NO_3-N/a remained after harvest. Doubling the spring N rate to 270 lb N/a doubled the amount of postharvest N to about 80 lb NO_3-N/a.

The data in Figure 36 are a sum of three sample depths. Figure 37 shows the amount of NO_3-N at each sampling depth from one field. Regardless of N rate, most of the residual N was measured in the surface foot of soil.

Thus, we can conclude that spring N, when applied between mid-February and mid-April, is not lost by leaching from spring rain. This result holds true even when an excess N rate is applied.

The key question, then, is whether the remaining NO_3-N is used by tall fescue for fall growth. If not, it would remain in the soil, where it might be leached by winter rains.
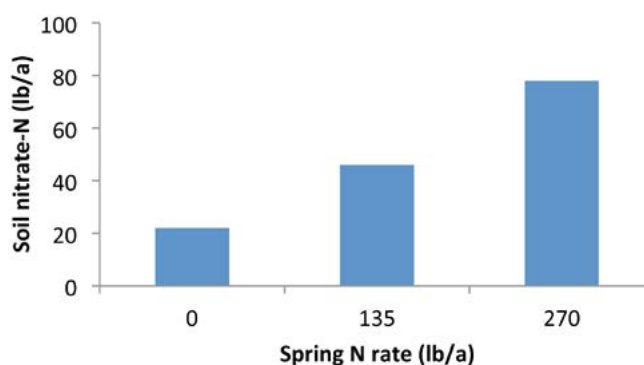

Figure 36.—Average amount of postharvest soil nitrate-N in 3 feet of soil from two western Oregon tall fescue seed fields. Data are from 3 years of soil testing after spring N application at three N rates. Data from OSU Seed Production Research Reports, 1998 through 2000; figure by John Hart.
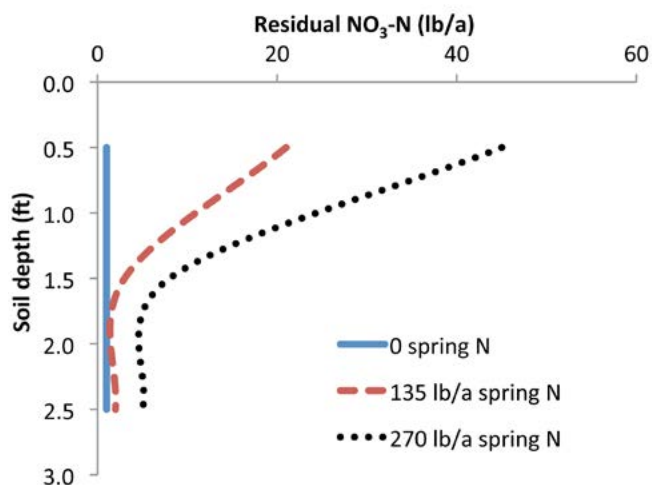

Figure 37.—Average distribution by depth of postharvest soil nitrate-N from a western Oregon tall fescue seed field. Data are from 3 years of soil testing after spring N application at three N rates. Data from OSU Seed Production Research Reports, 1998 through 2000; figure by John Hart.

Figure 38.—Tall fescue roots efficiently scavenge nitrate-N remaining in the soil following harvest.

Tom Chastain, © Oregon State University

Nicole Anderson, © Oregon State University

Figure 39.—Some NO_3-N from spring N application remains in the soil after harvest, indicating that spring N is not lost by leaching from spring rains.

Appendix B—*continued*. Tall Fescue Efficiently Uses N

Fortunately, tall fescue roots are also highly concentrated in the top foot of soil, where the residual NO_3-N is found (Figures 40 and 41). Thus, they are able to use the available N. In effect, the residual NO_3-N is parallel to having a "built-in" cover crop to supply N to tall fescue for fall growth.

Nitrogen measured in the above-ground portion of a tall fescue seed crop at harvest supports the concept that when N is applied at recommended rates, it is used by the crop. When N was applied at 90 to 180 lb/a in the spring, more than that amount was measured in the above-ground portion of the crop (Figure 42). The amount of N in the crop increased with increasing spring N rate until the spring N rate reached 180 lb/a. At this spring N rate, the above-ground portion of the crop contained 185 lb N/a.

The amount of residual soil NO_3-N measured in treatments receiving 270 lb N/a in the spring was approximately the difference between the amount applied (270 lb/a) and the amount in the crop (185 lb/a), i.e., 85 lb/a.

Postharvest soil NO_3-N for a tall fescue seed crop is about double the amount following a perennial ryegrass seed crop. One possible reason for this difference is root distribution. Root distribution in a 3-year-old tall fescue seed crop (Figure 41) is similar to root distribution for a perennial ryegrass seed crop of the same age. However, perennial ryegrass row spacing is about half that for tall fescue, filling the area between rows with roots.

Conclusion

Use of spring N at recommended rates of 100 to 140 lb/a, in addition to 20 to 40 lb/a in fall, provides adequate N for a tall fescue seed crop while creating minimal, if any, potential for loss of N to groundwater from leaching.
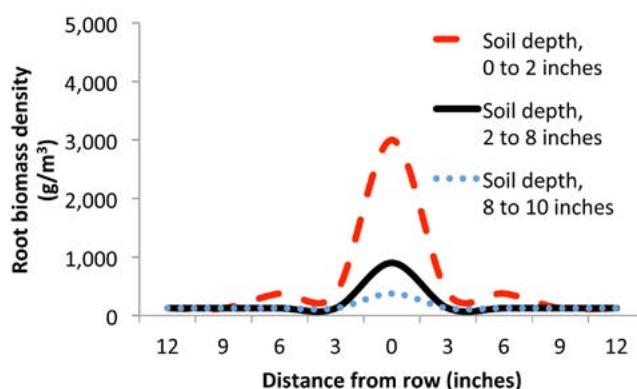

Figure 40.—Root distribution from a western Oregon first-year tall fescue seed field. Data from Chastain, et al. (2000); figure by John Hart.
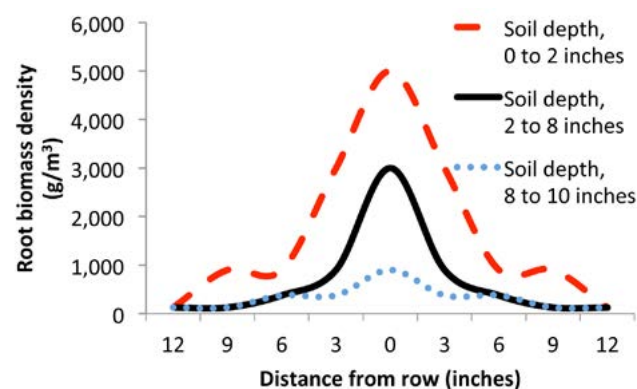

Figure 41.—Root distribution from a western Oregon third-year tall fescue seed field. Data from Chastain, et al. (2000); figure by John Hart.
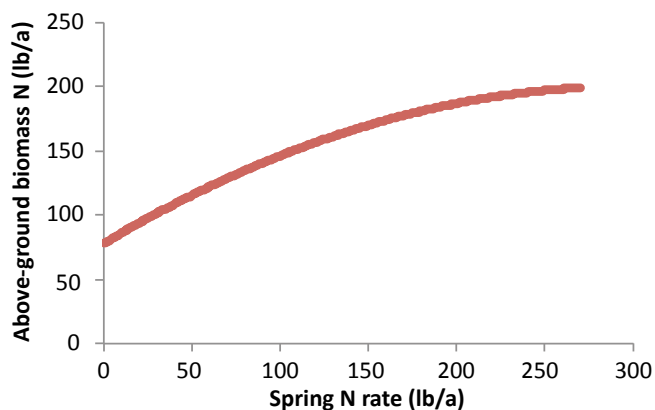

Figure 42.—Three-year average of N in above-ground biomass at harvest from three western Oregon tall fescue seed fields. Data from Young, Mellbye, et al. (2003); figure by John Hart.

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Appendix C. Comparison of Urea and a Mixture of Polymer-coated and Uncoated Urea for Tall Fescue Seed Production

Coatings have been added to fertilizer materials for decades. Many materials are lightly coated with clay or another material to prevent "caking" and ensure flow through augers and drill tubes.

About 40 years ago, coatings such as sulfur began to be applied to urea to control N availability, i.e., to provide N gradually rather than in a large "dose." Chemical additives, but not necessarily coatings, have been used for decades to inhibit conversion of N to the nitrate form (nitrification) or to slow volatile loss of N from urea.

Nitrification inhibitors can reduce N loss where leaching may move nitrate-N below the root zone. The potential for leaching loss of N is highest when the entire season's N is supplied before or at planting to an annual crop such as corn. In rain-fed corn production systems such as those found in the midwestern and southeastern U.S., N can be leached if all or a substantial amount is applied early in the growing season. A number of nitrification inhibitors were produced for this environment. See OSU Extension publication EM 9010-E, *Sweet Corn Nutrient Management Guide (Western Oregon),* for information about use of nitrification inhibitors in western Oregon (see "For More Information," page 19).

Leaching loss is not considered a problem for cool-season perennial grass seed production in western Oregon. Crop demand and N supply can be synchronized by timing N application to meet N demand and by splitting spring N application, common practices of most grass seed growers. Thus, nitrification inhibitors are not needed in these production systems.

Table 8.—Average annual seed yield with uncoated urea or a mixture of uncoated urea and polymer-coated urea as the spring N source.

Year	N rate (lb/a)	N from uncoated urea (lb/a)	N from polymer-coated urea (lb/a)	Seed yield (lb/a)	Difference in seed yield (lb/a)
1998	135	95	40	1,776	
	135	135	—	1,807	-31
1998	135	95	40	1,834	
	135	135	—	1,571	+263
1998	180	100	80	2,240	
	180	180	—	1,997	+243
1999	135	95	40	1,153	
	135	135	—	1,361	-208
1999	135	95	40	1,530	
	135	135	—	1,511	+19
Average	—	—	—	—	+57

Polymer-coated urea

Polymer or plastic-like coatings are another treatment applied to fertilizer, primarily urea. Polymers control the rate of granule dissolution, allowing N release and availability for a prolonged time. This feature is desirable where consistent growth and color are important, such as in turf.

Polymer coatings also act as a urease inhibitor. Urease inhibitors block conversion of urea N to a form than can be lost to the atmosphere. A relatively new coating, Agrotain, is a urease inhibitor (Figure 43).

Figure 43.—Agrotain, a relatively new polymer-coated urea, is being evaluated for use in grass seed production in Oregon.

John Hart, © Oregon State University

Appendix C. Comparison of Urea and a Mixture of Polymer-coated and Uncoated Urea for Tall Fescue Seed Production

Before choosing to use a coated product, two questions must be answered: (1) do they perform as advertised? and (2) do they provide economic benefit by increasing yield or reducing the required N rate?

The answer to the first question is "yes" for both polymer-coated urea and Agrotain. Evaluation of the economic benefit of polymer-coated material follows. The OSU Extension Service is currently investigating the utility of Agrotain for grass seed production in western Oregon.

Data from 1998 and 1999 experiments in growers' tall fescue fields are summarized in Table 8 (page 29). In three of five situations during a 2-year period, a mixture of polymer-coated and uncoated urea increased seed yield compared to yield from plots fertilized with only uncoated urea. The average seed yield increase was 57 lb/a. However, the difference in seed yield between the two N sources varied from positive to negative, changed annually, and was inconsistent in magnitude.

The average tall fescue seed yield increase with use of a mix of polymer-coated and uncoated urea (57 lb/a or about 3.5 percent) is the same as that measured in perennial ryegrass when polymer-coated materials were used. The complete report on use of polymer-coated urea with perennial ryegrass is available in *2008 Seed Production Research at Oregon State University* (Hart, et al., 2009).

Conclusion

Use of a mixture of polymer-coated and uncoated urea produced a small average seed yield increase in tall fescue, when compared to uncoated urea alone. However, the difference was inconsistent and unpredictable. For these reasons, application of polymer-coated urea is not recommended for tall fescue seed production in western Oregon.

Tom Chastain, © Oregon State University

Figure 44.—Use of polymer-coated urea has not produced a significant or consistent increase in seed yield and is not recommended for tall fescue seed production in Oregon.

Appendix D. Chloride in Tall Fescue Seed Production

In several areas of the western U.S., K application produced an increase in crop yield even when soil test K was adequate or high. Many of these observations were for wheat and barley. Meanwhile, in western Oregon, wheat producers began the practice of spring Cl application to reduce yield loss from take-all root rot. These two practices raised the question of whether spring application of KCl could increase yield of grass grown for seed.

OSU research in 1984 found that spring application of KCl did not significantly increase perennial ryegrass seed yield, although the thousand seed weight did increase (Table 9).

The 75 lb Cl/a rate (165 lb KCl/a) provided an increase in thousand seed weight and a trend of increased seed yield. The increase in seed yield was small—slightly more than 6 percent. This type of yield increase is indicative of a slight nutrient deficiency. The 225 lb Cl/a rate did not further increase thousand seed weight or yield.

Table 9.—Effect of potassium chloride (KCl) application on seed yield and 1,000-seed weight of perennial ryegrass.[1]

KCl (lb/a)	Cl (lb/a)	Seed yield (lb/a)[2]	Seed weight (g/1,000)[2]
0	0	1,770[a]	1.610[a]
165	75	1,884[a]	1.654[b]
500	225	1,890[a]	1.647[b]

[1]First-year stand of 'Ovation' perennial ryegrass, 1984.

[2]Means with the same letters are not significantly different (P=0.05).

The results from this research led us to question which nutrient (K or Cl) was responsible for the differences measured. To determine the effect of each nutrient, a variety of treatments were applied to first- and second-year perennial ryegrass seed crops: potassium chloride (KCl), potassium sulfate (K_2SO_4), calcium chloride ($CaCl_2$), and no K or Cl. This research was conducted with 'Ovation' perennial ryegrass in 1985 and 1986 on small plots at the OSU Hyslop Field Research Laboratory. At this time, burning was still used as a residue management practice.

The K and Cl materials were applied during the first week of March in both years. Soil test K values ranged from 163 to 234 ppm, well above the critical level of 100 ppm for perennial ryegrass seed crops.

The application of K as K_2SO_4 did not increase seed yield (Table 10). Chloride, applied in the spring as KCl or $CaCl_2$, often resulted in a small and sometimes significant seed yield increase. Thus, the yield increase sometimes resulting from KCl application is likely the result of overcoming Cl deficiency rather than improved K nutrition.

However, application of Cl increased seed yield only in 1985. As in the 1984 research with KCl, the seed yield increase was small, only about 100 lb/a. The 1985 crop year was considered wet, while conditions in 1986 were considered dry. The dry conditions were not a detriment to seed yield, as yields were approximately the same in both years.

Table 10.—The effect of K and Cl application on seed yield of first- and second-year stands of perennial ryegrass.[1,2]

Treatment	Cl rate (lb/a)	Seed yield (year and stand age)			
		1985 (first-year) (lb/a)	1985 (second-year) (lb/a)	1986 (first-year) (lb/a)	1986 (second-year) (lb/a)
Check	0	1,565[a]	1,304[a]	1,744[a]	1,230[a]
KCl	225	1,661[ab]	1,407[b]	1,762[a]	1,158[a]
K_2SO_4	0	1,640[ab]	1,314[a]	1,794[a]	1,144[a]
$CaCl_2$	225	1,714[b]	1,384[b]	1,714[a]	1,214[a]

[1]'Ovation' perennial ryegrass, 1985 and 1986.

[2]Means with the same letter are not significantly different (P=0.05).

Appendix D—*continued*. Chloride in Tall Fescue Seed Production

Additional research was initiated for cool-season grass species grown for seed in 2003 and repeated in 2004. This research measured yield response to spring Cl application in on-farm plots over a range of soil and environmental conditions. Current grower practices of applying additional KCl after straw removal were followed.

In both years, spring application of Cl increased Cl concentration in tall fescue flag leaf samples (Table 11). The flag leaf tissue data demonstrate that spring-applied Cl is assimilated or "taken up" by the crop.

Similar to the earlier research with perennial ryegrass, Cl application increased thousand seed weight approximately 3 percent, but did not increase seed yield. Spring K application did not increase seed weight or seed yield. Seed yield increase from application of K was not expected, as soil test K was adequate at both sites.

In Table 11, data are presented only from 2003. Data from 2004 and additional information for 2004 can be found in *2003*

and 2004 Seed Production Research at Oregon State University, USDA-ARS Cooperating (Hart, et al., 2004 and 2005).

Conclusion

When soil test K is adequate, the need for KCl fertilizer to supply either K or Cl to western Oregon grass seed fields is limited. Such need is likely to be caused by circumstances such as root disease or soil compaction, rather than by nutrient deficiency. When soil test K is above 150 ppm, maintenance application of potash fertilizer is not necessary to produce top grass seed yield. Furthermore, application of KCl to supply Cl is not recommended unless soil and tissue analyses indicate that Cl supply is low.

Table 11.—Flag leaf tissue Cl, tissue K, 1,000-seed weight, and seed yield after spring application of K and Cl fertilizers.[1,2]

Treatment		Tissue Cl (ppm)	Tissue K (%)	Seed weight (g/1,000)	Seed yield (lb/a)
K$_2$O (lb/a)	Cl (lb/a)				
0	0	2,256[a]	1.48[a]	2.30[a]	1,869[a]
88	0	2,058[a]	1.47[a]	2.32[a]	1,750[a]
44	35	3,378[b]	1.53[a]	2.37[ab]	1,847[a]
88	70	5,509[c]	1.56[a]	2.30[a]	1,795[a]
176	140	8,188[d]	1.52[a]	2.48[c]	1,838[a]

[1]'Rebel' tall fescue, 2003.

[2]Means with the same letter are not significantly different (P=0.1).

Appendix E. Substantiating K Requirement for Tall Fescue Seed Production

Growers and field representatives often believe that OSU Extension Service nutrient recommendations are too conservative. In fact, these recommendations are liberal. Potassium recommendations for tall fescue seed production are an example.

In Table 3 (page 14), no K fertilizer is recommended when soil test K values are above 150 ppm. Above this soil test concentration, no seed yield increase from K application has been measured.

This conclusion is based on western Oregon research, where seed yield was measured in two tall fescue fields with 3 years of K application (Table 12). Where initial soil test K was low (55 ppm in the 0- to 6-inch depth), seed yield increased after 2 years of K application, leading to the conclusion that soil test K was inadequate.

At the high soil test K site, the initial 0- to 6-inch depth soil test K value was 218 ppm. The 2-year average seed yield for plots receiving K, either as fertilizer or from burning straw, was 1,346 lb/a. Where no K was applied and straw was removed, yield was higher (1,427 lb/a), indicating that soil test K was adequate for crop growth and seed production.

These data are in agreement with nutrient solution concentration and potted greenhouse experiments. The critical K tissue concentration was 0.6 percent for the potted experiment and between 0.39 and 0.78 percent in the nutrient solution study (deWit, et al., 1963; Bailey, 1989).

Table 13 offers additional confirmation of these conclusions. In this OSU research, yield and tissue K concentration increased with the total amount of K supplied on sites with soil test K below 150 ppm.

Conclusion

When soil test K is above 150 ppm, no seed yield increase from K application has been measured and no K fertilizer is recommended.

Table 12.—Tall fescue seed yield from plots in two western Oregon grower fields.[1]

| Residue management | K rate (lb/a) | Seed yield (lb/a) | | | | | |
| | | Low soil test K site (55 ppm) | | | High soil test K site (218 ppm) | | |
		Year 1	Year 2	Average	Year 1	Year 2	Average
Removed	0	1,056	1,268	1,162	1,169	1,684	1,427
Removed	30	1,152	1,325	1,239	1,175	1,825	1,500
Burned	0	1,040	1,286	1,163	646	1,890	1,268
Burned	30	1,155	1,335	1,245	760	1,780	1,270

[1]Third-year data not reported, as plots were damaged by burn after second year.

Table 13.—Average 'Martin' tall fescue seed yield, straw K content and concentration, and soil test data.[1]

Straw treatment	K fertilizer (lb/a)	Seed yield (lb/a)	In straw (lb/a)	In straw (%)	From fertilizer and straw (lb/a)	Potassium Soil test 0 to 1 inch (ppm)	0 to 6 inches (ppm)
Removed	0	1,268	26	0.37	0	57	48
Removed	30	1,325	45	0.57	30	60	53
Burned	0	1,286	52	0.63	52	88	70
Burned	30	1,335	62	0.75	92	89	72

[1]Treatments on a silt loam soil. Data collected after second year of trial.

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Appendix F. Sulfur in Western Oregon Soils

Crop need for S is not easily measured, nor are situations requiring S application easy to identify. Therefore, routine S application is recommended for perennial cool-season grass seed production. Tall fescue use of S is the basis for the amount to apply and is shown in Figures 28 and 29 (page 16).

Application timing is flexible. *A spring S application of 15 to 25 lb S/a is preferred, but S also can be applied in the fall. An alternative is to apply 30 to 50 lb S/a every other year.* These recommendations are based on a combination of S plant use, mobility, immobilization, and accumulation in subsoil.

This flexibility in timing results from S behavior in soil. The discussion below focuses on S behavior in western Oregon soil, with a comparison to NO_3-N.

NO_3-N mobility in soil

The plant-available form of S is sulfate (SO_4-S), an anion. Other plant nutrients available as anions are phosphate, borate, chloride, and nitrate. Nitrate-N is very soluble and mobile, traits well understood by growers.

Measurement of soil NO_3-N over time in a western Oregon hop yard showed NO_3-N mobility in the soil (Figure 45). Total postharvest NO_3-N in the top 5 feet of soil was measured on October 2 and in December. During this time, NO_3-N decreased by 35 percent. Specifically, NO_3-N in the surface foot decreased, while an increase was measured between 2 and 3 feet. The same trend was found for samples collected in January and March.

This example is typical for western Oregon when NO_3-N remains in the soil following harvest and no crop is present to use the N. The NO_3-N readily leaches with fall and winter rain.

S mobility in soil

A common misconception is that SO_4-S behaves similarly to NO_3-N. This idea might originate from SO_4-S measurements in the surface 6 inches. After applying 45 lb S/a for 2 years to an uncropped area, SO_4-S in the surface 6 inches was almost the same as before S application, indicating that leaching likely occurred (Figure 46). However, measuring SO_4-S only in the surface 6 inches overlooks critical aspects of the situation.

Adsorption. It is important to note that SO_4-S, unlike NO_3-N, is adsorbed (attracted) to clay particles. In Figure 46, extractable SO_4-S concentration increases from 10 to 20 inches and is highest between 20 and 40 inches. The amount of the SO_4-S increase in these lower depths depends on clay content of the soil.
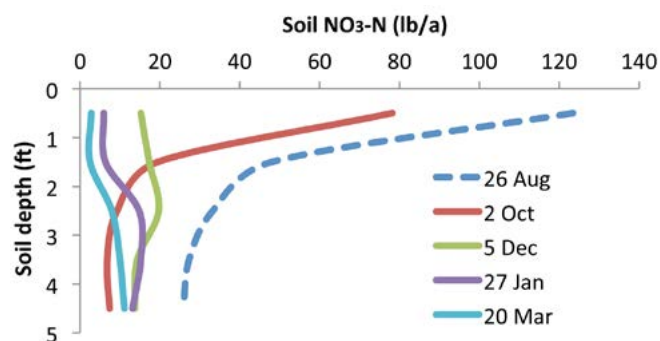

Figure 45.—Temporal soil NO_3-N distribution in a western Oregon hop yard (Amity silt loam soil). Harvest occurred after the August 26, 1992 sample was collected. Data from Christensen (unpublished); figure by John Hart.
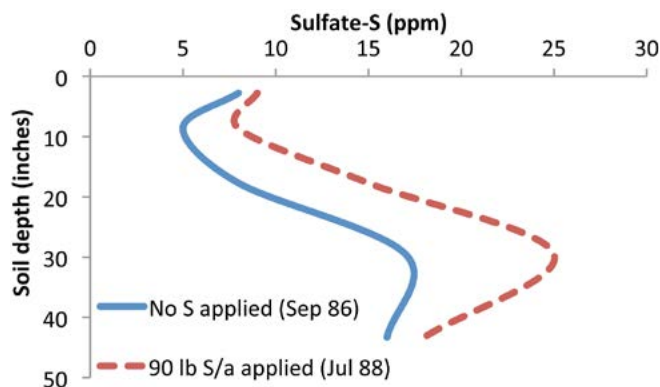

Figure 46.—Distribution of SO_4-S in Woodburn silt loam before and after two annual applications of 45 lb S/a and no crop removal. Data from Castellano (1990); figure by John Hart.

Appendix F—*continued*. Sulfur in Western Oregon Soils

As seen in Figure 47, the higher the clay content, the more SO_4-S is adsorbed to soil particles.

In contrast, soil NO_3-N is not related to clay content. This statement is supported by the fact that the Amity soil series (Figure 45) and Woodburn soil series (Figures 46 and 48) have similar clay concentration and distribution. If NO_3-N were retained by clay, the NO_3-N distribution shown in Figure 45 would be expected to be similar to that of SO_4-S in Figure 46. This was not the case, however.

Leaching. SO_4-S does leach, but not does not do so readily when retained by clay. Movement from the surface and accumulation in subsurface soil is shown in Figure 46—the "Jul-88" measurement of SO_4-S after application of 90 lb S/a.

Leaching of SO_4-S is much more likely in a sandy soil. Research compared SO_4-S leaching on a sandy soil (Deschutes, 5 percent clay), a soil with moderate clay content (Willamette, 20 percent), and a soil with a relatively high amount of clay (Jory, 40 percent). After application of 40 lb S/a and 8 inches of water to these soils in a laboratory column experiment, more than half the applied SO_4-S was leached from Deschutes soil. Almost all of the remaining SO_4-S was below the 12-inch soil depth. In contrast, more than half the applied SO_4-S remained in the top 12 inches in the Willamette soil, and approximately 90 percent of

the SO_4-S remained in the top 4 inches of the Jory soil (Figure 47).

Since the Deschutes soil does not retain SO_4-S, annual S application is routinely recommended for many crops in central Oregon, where this soil is common.

Mechanism of SO_4-S retention. The retention of SO_4-S is controlled by equilibrium between solution S and soil-adsorbed S, rather than by a maximum amount governed by anion or cation exchange capacity. The SO_4-S concentration before and after S fertilizer application in Figure 46 illustrates this concept. During the 2-year span of this field research, 90 lb S/a was applied, and no crop was grown. The increase in S content (82 lb/a) was approximately the same as the amount applied.

In laboratory experiments, SO_4-S retention increased proportionally with increasing S application until the equivalent application of more than 500 lb S/a. The experiment did not attempt to measure maximum retention, nor should the results be used to advocate high S application rates. It is simply an example of how SO_4-S behaves in western Oregon soils.

If the retention of SO_4-S is controlled by equilibrium with solution S, then desorption or removal by leaching should occur when no S is added. SO_4-S as an isotope of S was added to soil from the Jory soil series in the laboratory.
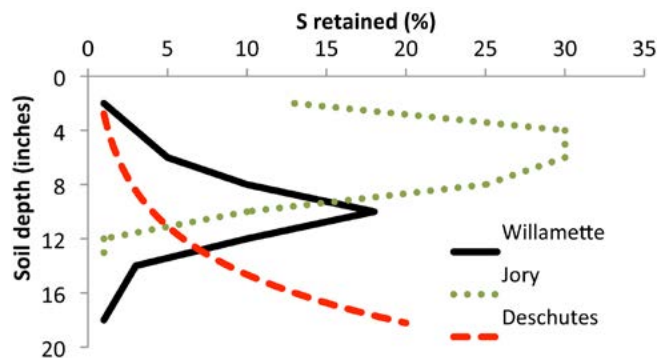

Figure 47.—Retention of SO_4-S in three Oregon soils. Deschutes = 5 percent clay; Willamette = 20 percent clay; Jory = 40 percent clay. Data from Chao, et al. (1962a); figure by John Hart.
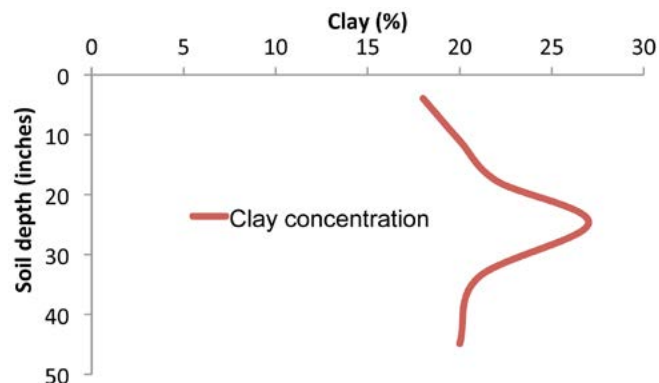

Figure 48.—Average clay concentration for the Woodburn soil series. Figure by John Hart.

Appendix F—*continued*. Sulfur in Western Oregon Soils

Water was then applied to the soil. Each extraction with water was approximately equivalent to total winter rainfall in western Oregon. The first extraction removed 35 to 45 percent of the applied SO_4-S. After two extractions, 35 percent of the SO_4-S remained, and after three extractions, 20 percent of applied SO_4-S remained (Figure 49).

Management implications

As seen in Figure 49, more than half the applied SO_4-S remained after the first extraction. Thus, even following a typical western Oregon rainy season, more than half of applied SO_4-S should be available for crop use the following growing season. Therefore, a single SO_4-S application should be able to provide for tall fescue needs for two growing seasons.

The examples above focused only on certain aspects of SO_4-S retention by soil. Other factors also play a role. Two common materials—lime and phosphate fertilizer—reduce SO_4-S retention or increase leaching by about 10 percent per year. Conversely, kaolinitic clay, found in "red hill" soils such as Jory, increases SO_4-S retention.
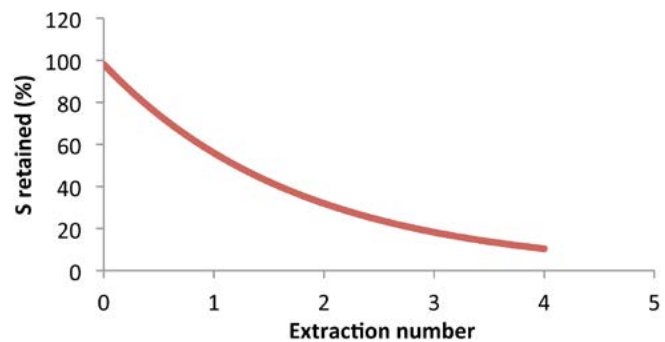

Figure 49.—Retention of SO_4-S in a Jory soil after successively extracting with water that approximated a single western Oregon seasonal rainfall total. Data from Chao, et al. (1962b); figure by John Hart.

Appendix G. Micronutrients for Western Oregon Grass Seed Production

Western Oregon growers are accustomed to applying micronutrients such as boron (B) to hops and clover crops, zinc (Zn) to sweet corn in the Stayton area, chloride (Cl) to winter wheat, molybdenum (Mo) to broccoli and cauliflower, and copper (Cu) to onions grown on peat/muck soils around the former Lake Labish. Since growers use micronutrients on numerous crops, many ask whether micronutrients should be applied to tall fescue fields.

Use of Cl for grass seed production is discussed in Appendix D, "Chloride in Tall Fescue Seed Production." Here we consider the need for B, Cu, Mo, Zn, manganese (Mn), and iron (Fe).

The name of these nutrients, micro or trace, is indicative of the amount found in a crop. Table 14 provides amounts of some micronutrients in grass seed crops.

Boron

Soil test B is naturally low in western Oregon soils. A survey conducted by OSU in the 1950s found that about 80 percent of western Oregon fields had soil test B below 0.5 ppm, the amount considered "critical."

Subsequent field research demonstrated dramatic seed yield increase in clover and sugar beets following B application. However, recent research in red clover did not produce a seed yield increase from B application.

Research in 1999 and 2000 examined the influence of B application on soil test B, tall fescue flag leaf B concentration, and seed yield on western Oregon field research sites. Tissue and soil test B levels increased with soil B applications (Table 15). An application of B usually more than

Table 14.—Average micronutrient content in seed and straw of tall fescue and perennial ryegrass.

Grass species		Weight of seed and straw (lb/a)	B (oz/a)	Cu (oz/a)	Zn (oz/a)
Tall fescue	Straw	5,000	0.6	0.2	1.0
	Seed	1,400	0.1	0.2	0.9
	Total	—	0.7	0.4	1.9
Perennial ryegrass	Straw	4,500	0.6	0.2	0.9
	Seed	1,500	0.1	0.2	1.0
	Total	—	0.7	0.4	1.9

Table 15.—Influence of soil B applications on soil test B, tall fescue flag leaf B concentration, and seed yield from western Oregon field research sites.[1]

Tall fescue variety	B rate (lb/a)[2]	Soil test B (ppm)[3]	Flag leaf B (ppm)[3]	Seed yield (lb/a)
'Duster'[4]	0	0.2	15	1,510
	1.25	1.1	30	1,530
'Kittyhawk SST'	0	0.2	12	1,360
	1.25	0.7	22	1,220
'Duster'	0	0.2	9	1,117
	1.25	0.3	32	1,102
'Kittyhawk SST'	0	0.3	12	1,389
	1.25	0.7	27	1,402
'Tomahawk'	0	0.2	14	2,239
	1.25	0.7	30	2,277

[1] 1999 and 2000.

[2] Boron applied in March as dry granular fertilizer mixed with urea.

[3] Soil and plant samples collected in May.

[4] Research conducted in 2000.

Appendix G—*continued*. Micronutrients for Western Oregon Grass Seed Production

doubled soil test B and flag leaf B concentration. However, average seed yield was not changed by B application.

Boron applied at 1 lb/a every 3 or 4 years may be used on a trial basis where soil test B is less than 0.3 ppm. To avoid potential toxicity, do not apply B with the seed at planting and do not use it every year.

Additional information about sites used in the B research (soil series and other soil test values) can be found in Mellbye and Gingrich (2000) and Mellbye, Gingrich, and Hart (2001).

Metallic micronutrients (Fe, Mn, Zn, and Cu)

Soil pH is a primary factor in the availability of the metallic trace nutrients Fe, Zn, and Mn. As soil pH increases, the solubility and availability of these nutrients decreases. The soil pH in Willamette Valley grass seed fields is commonly below 6, a level at which sufficient amounts of Fe, Mn, and Zn are available for grass seed production.

One often hears of increased grass seed yield from spring foliar micronutrient application. Foliar Zn, Cu, and Mn can act as fungicides as well as plant nutrients. Fungicidal and nutritional responses of foliar nutrient application are difficult to distinguish, and plants may benefit more from

the fungicidal activity of these elements than from increased nutrient availability.

Unlike other metallic trace elements, Cu availability is not influenced by soil pH. In Oregon, Cu availability is almost always sufficient for grass seed production. The only documented Cu deficiencies in Oregon are in peat/muck soils such as those found around the former Lake Labish and in the Klamath Basin.

Molybdenum (Mo)

Molybdenum is a trace nutrient used in legume seed and some vegetable seed production. Legumes and brassica crops such as cauliflower need more Mo than other plant species, including grass seed crops. Soil pH regulates Mo availability; however, in contrast to the trace metal nutrients, Mo availability decreases as soil pH decreases. Liming increases the availability of Mo. Molybdenum application is not recommended for tall fescue seed production in western Oregon.

Conclusion

Most soils in the Willamette Valley are not deficient in micronutrients for grass seed production. Growers should be skeptical about sales pitches that promote their use. Money spent on special micronutrient blends for grass seed production is most often an unnecessary expense.

## Appendix H. Western Oregon Research on Which This Publication Is Based

1953: Rates of N, a single rate of P, and a single treatment with K were applied to 'Alta' tall fescue fields in Marion and Washington counties. In Marion County, the maximum yield was achieved with 140 lb N/a, plus 80 lb P_2O_5/a, but the economic optimum was 60 lb N/a. No yield increase from any of the nutrients supplied was measured in Washington County, but severe lodging created harvest difficulties.

1957–1959: Movement of S fertilizer labeled with S^{35} was followed in soil columns receiving varying amounts of $CaSO_4$ and water. As the amount of water applied increased, sulfate leaching increased. As sulfate application rate increased, the loss of sulfate from leaching increased, even when percolation water was constant. Amount and type of clay, as well as iron and aluminum oxides, affected the amount of retained S.

1982–1986: Restrictions on the use of open field burning as a postharvest residue management tool for cool-season grass seed production were implemented. Growers began searching for alternative residue management options. Following experiences with wheat straw and N immobilization, fall and spring N treatments were used in conjunction with urea-sulfuric acid in an attempt to decompose straw after chopping or residue after baling, or to eliminate/reduce early spring growth. When urea sulfuric acid was applied to 'Fawn' tall fescue on April 1, seed yield decreased and the crop did not respond to fall N application.

1984: Increasing the spring N rate from 80 to 134 lb/a did not increase 'Fawn' tall fescue seed yield, nor was an interaction with Parlay plant growth regulator measured.

1986–1989: Spring N rates of 90, 130, and 170 lb/a were compared for 'Bonanza', 'Rebel', and 'Falcon' tall fescue, in combination with other production variables, such as row spacing and residue management. Spring N in excess of 130 lb/a generally reduced seed yield. Spring N timing did not change seed yield, regardless of whether all of the N was applied during the
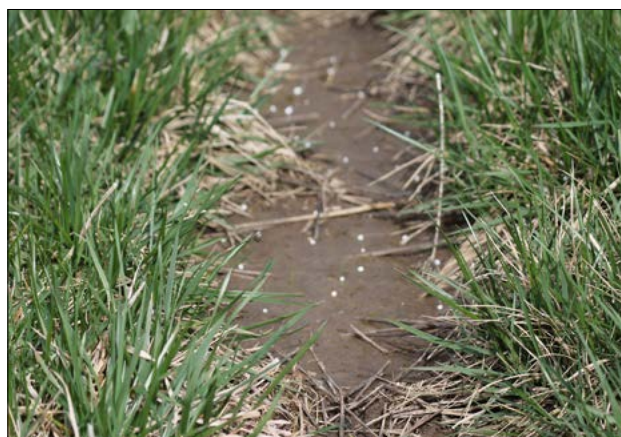
Figure 50.—Research on grower fields and at OSU research facilities have sought to determine optimum rates, timing, and materials for fertilization of tall fescue grown for seed production.

vegetative development stage, all was applied during the reproductive development stage, or application was split equally between the two stages.

Effects of row spacing and seeding rate on seed yield and yield components were measured for 2 years. Row spacings of 15, 30, 45, 60, 75, and 90 cm were used. The total number of vegetative tillers was less at wider row spacings in the spring following establishment; however, the tiller population was made up of a greater percentage of larger tillers. Fertile tiller number at seed maturity was reduced at wider spacings. A greater number of spikelets per panicle was observed at wider row spacings in both years. Total harvested dry weight and straw weight were reduced at wider row spacings, and harvest index was increased. Optimum row spacing for first-year seed production was between 30 and 60 cm; the second-year seed crop was highest at wider spacings.

1987: A shift from open field burning to removal of straw after baling was recognized as an interruption of nutrient cycling on which nutrient management recommendations traditionally had been made. As an initial measure of changes created by differing straw management practices, a survey of more than 70 western Oregon grass seed fields was performed. Measurement of biomass

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nutrient content and soil test values from depths of 0 to 1, 1 to 3, and 3 to 6 inches documented nutrient removal with baling. Soil test stratification was also found, especially for soil pH, depending on stand age and straw management.

1988–1990: Before applying nutrients as fertilizer, growers must choose an application rate and time to apply the material. The choice of application time should take into account plant assimilation and nutrient mobility. To determine above-ground nutrient assimilation, above-ground biomass samples of 'Fawn' and 'Rebel' tall fescue were collected on six dates, ranging from initiation of spring growth to physiological maturity. Seasonal and daily nutrient assimilation and growth were determined from the data. Grass growth followed a sigmoidal pattern when plotted for time or days and a linear pattern when measured for heat units. Nutrient accumulation usually preceded dry matter production or growth. For example, by the latter part of April, both tall fescue varieties accumulated about 50 percent of their dry matter, compared to 40 to 45 percent of N, 60 percent of P, 55 to 70 percent of K, and 60 percent of S.

The effects of postharvest residue management and K fertilizer application were investigated in two commercial tall fescue seed fields for 3 years. Removing straw decreased soil test K concentration in the surface 6 inches of soil. Even when soil test K was initially low (below 75 ppm), yield increases from K fertilizer application varied yearly.

The decline in soil pH in the surface 3 inches of tall fescue seed fields as a stand ages was documented in a 1987 survey. Phosphorus is routinely top-dressed to this acidic environment. Phosphorus supply to a turf-type tall fescue ('Falcon') was evaluated at OSU's Hyslop Field Research Laboratory. Initial soil pH was 5.2, and soil test P was 60 ppm. Various rates of P (0 to 200 lb P_2O_5/a) and method of P application (surface band or broadcast) were tested on limed

and unlimed areas. Seed yield did not increase from P application as expected, nor did lime application increase seed yield.

1989–1991: Effects of 60, 100, and 140 lb N/a applied at the double-row stage were measured on 'Rebel II', a turf-type cultivar, and 'Martin', a forage-type tall fescue. Between 25 and 42 lb N/a was applied in the fall. Seed yield of 'Rebel II' increased slightly as the spring N rate increased from 60 to 140 lb/a. Seed yield of 'Martin' did not change with N rate. Nitrogen requirements for nonburning treatments were the same as for treatments where residue was burned.

1989–1991: A long-term investigation to consider the interaction between postharvest residue management and soil test N and K was established. Research was conducted on two perennial ryegrass and two tall fescue fields. Removal of straw following seed harvest removed significantly more K than that "lost" in the seed crop alone. As a result, soil test K was lower when crop residues were removed. On the other hand, changing to a nonthermal cropping system did not result in a significant loss of N, as grass straw contains only about 1 percent N.

1993: Plant growth and nutrient accumulation were determined in four southern Willamette Valley tall fescue fields. Postharvest residue was removed with vacuum sweep or chopping the full straw load. Each residue management practice was tested on two fields—one harvested for the second time and the other harvested for the fourth time. Plant and soil samples were collected six times from March through July. Nitrogen accumulation preceded plant growth. By early May, 90 percent of the season's total N had been accumulated in the above-ground portion of the tall fescue crop, compared to 35 to 45 percent of the biomass. This pattern was consistent for all residue management treatments. Residue management treatments had only small effects on soil ammonium and nitrate-N. Little evidence was found that either immobilization or mineralization of N caused

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by returning chopped straw to the soil surface was sufficiently large to change N fertilizer management practices.

1996: An early May application of 100 lb N/a in excess of the grower-applied rate (120 lb N/a) was made to a 'Bonanza 2' field of tall fescue. Crop N uptake doubled from 90 to 180 lb/a with the additional N. A few small differences in ammonium and nitrate-N levels were measured to a depth of 5 feet. The late-season N was utilized by the crop, demonstrating the ability of grass crops to limit leaching loss of N fertilizer.

1998–2002: Large-scale on-farm trials were conducted in perennial ryegrass, tall fescue, fine fescue, and annual ryegrass over several seasons to evaluate the optimal spring N rate. Experimental plots in commercial tall fescue seed production fields located in Linn, Lane, and Marion counties received the same treatments for 3 years: 0, 45, 90, 135, 180, 225, and 270 lb N/a as a 50/50 split spring application. A spring N rate of 90 to 135 lb/a was adequate for 2,000 lb/a seed yield or more. Increasing the N rate above this range did not increase seed yield. Soil test results at optimal use rates showed little potential for leaching losses, as applied N was efficiently used by the crop.

Figure 51.—Combinations of fall and spring N were evaluated in perennial ryegrass at Hyslop Field Research Laboratory.

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1998–2008: Ensuring that N availability is synchronized with crop demand is a longstanding and universal goal of growers. In an effort to meet this goal, growers experimented with a controlled-release fertilizer (polymer-coated urea). By matching release rate with crop demand, controlled-release N is an alternative to synchronizing N application to meet N demand and to splitting spring N application, common practices of most grass seed growers. Between 40 and 120 lb N/a was supplied by polymer-coated urea in 10 experiments over a 10-year period. The seed yield increase from polymer-coated urea application was not consistent or significantly different from that with urea application. No relationship existed between polymer-coated N supply and seed yield increase. For these reasons, application of polymer-coated urea is not recommended for tall fescue seed production in western Oregon.

1999–2000: Boron is the most widespread micronutrient deficiency in western Oregon. However, crops vary widely in B need, with dicotyledonous plants having a higher requirement than monocotyledonous plants (e.g., grasses). Most grass seed fields in western Oregon have very low soil test B values, which raised the question of B need. To test the need for B in tall fescue grass seed production, 0 and 1.25 lb B/a was soil applied at two sites for 2 years and at one site for a single year. Tall fescue seed yield did not increase with B application.

2000: Nitrogen and above-ground biomass accumulation were measured by calendar date and Growing Degree Days (GDD) or Heat Unit (HU) accumulation. By the end of April, or accumulation of approximately 1,200 GDD, the tall fescue cultivar 'Hounddog' accumulated the maximum amount of N.

2002–2004: Combinations of fall and spring N were used at four locations in western Oregon— OSU Hyslop Field Research Laboratory and grower fields in Linn, Marion, and Yamhill counties (Figure 51). The highest seed yields

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were produced when fall N was applied. Fall N substantially increased fertile tiller number.

2003 and 2004: Field representatives for agricultural chemical suppliers and some agricultural testing laboratories began recommending spring K application, based on reported perennial grass seed yield increase from application of spring-applied K. To determine whether spring K application increased tall fescue grass seed yield and whether the yield increase resulted from application of K or Cl, large-scale nonreplicated plots were established in Linn and Marion county commercial tall fescue seed fields. No seed yield or seed weight increase was measured from application of either Cl or K, even though Cl application routinely increased tissue Cl concentration.

2005: The N mineralization soil test (Nmin) has the ability to accurately predict spring N fertilizer needs for winter wheat grown in western Oregon. Growers desire a similar spring N rate prediction tool for production of cool-season grasses. On eight western Oregon sites seeded to tall fescue, no relationship was found between the Nmin and seed yield.

2010–2012: Seed yield losses can be as severe as 70 percent when stem rust is not managed. Field studies were conducted to determine the effects on seed yield of a strobilurin-containing fungicide applied at two growth stages in tall fescue crops

Figure 52.—Nmin and KCl plot research.

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in western Oregon. Weather conditions were favorable for disease development in 2012; however, cool and wet conditions in 2010 and 2011 resulted in low pressure from stem rust. Strobilurin-containing fungicide treatments increased seed yield 17 percent over the untreated control across sites and years, but the greatest seed yield increases were noted when stem rust pressure was highest (2012). Seed yield increases were attributable to a combination of increased seed number and weight. Cleanout was reduced by up to 18 percent with fungicide treatments. While fungicide treatment increased seed yield even with low disease incidence and severity, there were no effects on plant growth or N metabolism.