

Nutrient Management for Pastures: Western Oregon and Western Washington

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Forage production is of primary importance to livestock enterprises and the agricultural economy in the Pacific Northwest. When properly managed, pastures can produce forage for pennies per pound of dry matter and can serve as the main feed source for western Oregon and Washington livestock operations.

Good soil fertility is an essential part of a successful forage management program. Science-based nutrient management, combined with a dense stand of grass or grass/clover species, can provide a sustainable source of forage. This publication provides nutrient management concepts and recommendations for western Oregon and western Washington pastures used primarily for grazing. It also includes concepts related to conserving forage as hay or silage when forage production exceeds grazing needs. The topics discussed in this publication will help livestock producers develop a sustainable forage production system.

Nutrient management practices may not be beneficial unless system-wide best management practices for pasture systems are implemented. Animal management practices have a tremendous influence on pasture productivity. Poor management practices, such as overgrazing and grazing animals on saturated soils, will greatly reduce or even eliminate the positive effects of soil fertility improvements. Therefore, a secondary goal of this publication is to address general pasture management practices that may affect the pasture's ability to respond to recommended nutrient management practices.

Forage management practices and nutrient use efficiency

The biological and economic response to a nutrient application to a pasture depends on several factors:

- **Species composition:** A dense stand of cool-season pasture grasses (e.g., tall fescue, orchardgrass, perennial ryegrass) and a clover species (e.g., white clover, subclover, red clover) will respond well to nutrient applications, assuming that the soil pH is appropriate for the species in the mix.
- **Plant density:** Early-establishment stands will likely be thin. As the pasture stand ages, tillering increases in grasses and branching increases in legumes, resulting in a denser stand. Younger, thinner stands are subject to weedy species invasion, while aged, dense stands provide a more competitive environment against invading weeds and native grasses.
- **Stage of growth:** Plants in the vegetative growth phase with adequate leaf area are more likely to show a response to a nutrient application than are overgrazed plants or plants that are close to maturity. Pasture plants are classified as being in growth phase I, II, or III, with phase II being the optimal phase for fertilizer application. Further guidance on how to adjust fertilizer applications and grazing management based on growth stage is provided in Appendix 1 (page 12). For more information on managing plants in pasture

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systems, see *The Western Oregon and Washington Pasture Calendar* (PNW 699).

- **Stand age:** The longer a pasture plant is present in a stand, the older are its genetics. Plant breeders have focused on genetic improvements that allow new forage cultivars to outperform older versions of the same species in growth rate, yield, digestibility, and other attributes. When a new stand is established, the resulting increase in pasture productivity may also promote an improved response to fertilizer applications.
- **Balance of soil nutrients before N applications:** If pasture soils are very low in an essential nutrient, forage yield will be limited by that nutrient even if other nutrients are applied. For example, if phosphorus (P) is the most limiting factor in a pasture, nitrogen (N) application will not provide the expected outcome. To get the best response from N applications, make sure all other essential plant nutrients are at recommended levels.

- **Amount of defoliation by grazing animals:** As animals graze the forages in a pasture, plant regrowth replaces the consumed forage. However, excessive defoliation caused by overgrazing will slow the rate of regrowth and will prevent plants from effectively using N and other critical plant nutrients in the soil.

Soil testing

Soil nutrient testing is essential to determine the amount of nutrients available in the soil for plant growth and how much fertilizer is needed to optimize forage yield and quality.

For new, conventionally tilled seedings, test the soil prior to planting. For established and no-till pastures, plan to have soil analyzed every 2 years if fertility is within recommended levels. Test annually if fertility is below recommended levels and nutrient deficiencies are common. Collect the samples near the same date each year, since nutrient levels vary seasonally.

Summary

Before planting

Lime	When soil pH is below 5.5, broadcast lime according to Table 2. See page 4.
Nitrogen (N)	Broadcast or band 20 to 25 lb N/acre. See page 5.
Phosphorus (P)	When soil test P is below 30 ppm, broadcast or band P according to Table 4. See page 10.
Potassium (K)	When soil test K is below 200 ppm, broadcast K according to Table 5. Banding K is permitted at less than 60 lb K ₂ O/acre. See page 10.
Sulfur (S)	Sulfate-S may be broadcast or band applied to new fields at a rate of 15 to 25 lb S/acre. See page 10.
Magnesium (Mg)	When soil test Mg is below 0.8 meq/100 g or 100 ppm, replace 1 ton lime/acre of the lime requirement with 1 ton dolomite/acre. See page 5.
Calcium (Ca)	When soil test Ca is below 5 meq/100 g or 1,000 ppm, apply 1 ton lime/acre. See page 4.
Boron (B)	For clover pastures, 2 to 3 lb B/acre is recommended when soil test B is below 0.7 ppm. Use a broadcast application; do not band B. See page 11.

Established stands

Lime	For stand age under 5 years, top-dress lime if pH in the top 6 to 8 inches is below 5.5. For stand age over 5 years, top-dress lime if pH in the top 2 inches is below 5.5. Follow Table 2, page 4.
Nitrogen (N)	Top-dress N when grass is actively growing in early spring and early fall. On irrigated pastures, apply additional N in the summer. See Table 3, Figure 4, and pages 6–9.
Phosphorus (P)	When soil test P is below 30 ppm, top-dress P in either the fall or spring. See Table 4 and page 10.
Potassium (K)	When soil test K is below 200 ppm, top-dress K in either the fall or spring. See Table 5 and page 10.
Sulfur (S)	Top-dress sulfate-S in the spring or fall at a rate of 20 to 30 lb S/acre every year or 40 to 50 lb S/acre every other year. See page 10.
Magnesium (Mg)	When soil test Mg is below 0.8 meq/100 g or 100 ppm, apply either 1 ton dolomite/acre (if pH < 5.5) or 500 lb K-Mag/acre (if pH > 5.5). See page 5.
Calcium (Ca)	When soil test Ca is below 5.0 meq/100 g or 1,000 ppm, apply 1 ton lime/acre. See page 4.
Boron (B)	For clover pastures, broadcast application of 2 to 3 lb B/acre is recommended when soil test B is below 0.7 ppm. See page 11.
Selenium (Se)	Refer to <i>Selenium Supplementation Strategies for Livestock in Oregon</i> (EM 9094) to determine whether you should consider correcting Se deficiencies in grazing animals via fertilizer applications. See page 11.
Molybdenum (Mo)	For clover pastures, Mo deficiencies can be corrected by following lime recommendations in this guide. See page 11.

Collect samples from the tillage depth, about 6 to 8 inches for pastures in this region. For complete instructions on how to take a soil sample, see *A Guide to Collecting Soil Samples for Farms and Gardens* (EC 628). Additional information on soil sampling frequency and the management unit approach can be found in *Monitoring Soil Nutrients Using a Management Unit Approach* (PNW 570).

For fields that have been established for more than 5 years and for no-till systems, a stratified sampling approach provides additional information for long-term management. Dividing the sample into two parts, surface to 2 inches and 2 to 6 inches, for separate analyses can reveal accumulation of less mobile nutrients near the soil surface. To learn more about the stratified sampling approach, see *Evaluating Soil Nutrients and pH by Depth in Situations of Limited or No Tillage in Western Oregon* (EM 9014).

For pastures west of the Cascades, soil samples should be analyzed for the following:

- pH (1:2 soil:water ratio)
- Lime requirement test (SMP buffer method)
- Plant-available phosphorus (P) (Bray P1 method)
- Extractable potassium (K), calcium (Ca), and magnesium (Mg)

In fields where clover and other legumes are grown, also analyze for hot-water-extractable boron (B).

Soil testing for nitrogen (N) and sulfur (S) in pasture systems is not recommended, as these tests are poor predictors of the plant availability of these nutrients.

When selecting a laboratory to analyze samples, contact the lab to confirm that they do the recommended tests and to determine shipping and handling procedures. To find a lab specializing in soil testing, refer to *Analytical Laboratories Serving Oregon* (EM 8677). A current list of soil testing labs that are accredited through the North American Proficiency Testing Performance Assessment Program (NAPT-PAP) can be found at <https://www.naptprogram.org/pap/labs>.

Soil acidity, lime, Ca, and Mg

Soil acidity

Soils in western Oregon and western Washington are naturally acidic. Repeated applications of ammonium-based N fertilizers can contribute to additional soil acidification.

Soil pH is a measure of soil acidity. Acidic soil conditions occur when soil pH levels are below 7.0. Soil pH decreases with increasing acidity.

As soils become more acidic, forage yields are reduced due to a combination of nutrient toxicities (aluminum or manganese) and nutrient deficiencies (P, K, Ca, Mo, or N). Highly acidic soils greatly limit the effectiveness of fertilizer applications, as chemical and biological processes in the soil prevent many nutrients from being in a plant-available form.

The recommended minimum soil pH for most grasses and legumes grown in pasture systems is between 5.5 and 6.0, depending on the plant species. Minimum recommended soil pH values for specific species are listed in Table 1.

Some plants may persist below these soil pH levels, depending on factors such as soil type and rooting depth. However, when soil pH is below recommended levels, forage yield and quality can decline dramatically in response to even a minor decrease in soil pH. Plant species shift can also occur at pH levels below 5.5, with acid-tolerant grasses such as bentgrass persisting over less acid-tolerant plant species such as white clover and orchardgrass. To learn more about general concepts related to soil acidity, see *Soil Acidity in Oregon* (EM 9061).

Applying N fertilizer will not combat acidity. More information on acidification and N fertilizers can be found on page 9 under “Nitrogen fertilizer source.”

Table 1. Minimum recommended soil pH levels for pasture plant species commonly grown in western Oregon and western Washington.

	Recommended minimum soil pH				
	5.0	5.2	5.5	5.8	6.0
	More acid tolerant -----> Less acid tolerant				
Grass	Bentgrass	—	Annual ryegrass Tall fescue Perennial ryegrass	Orchardgrass	—
Legumes	—	Subterranean clover	Crimson clover Peas Vetch	White clover	Red clover

Adapted from *Soil Acidity in Oregon: Understanding and Using Concepts for Crop Production* (EM 9061) Appendix A.

Lime

The most cost-effective method for correcting soil acidity is lime application. Lime products originate from ground limestone, which is composed of calcium carbonate compounds. The Ca ions from lime replace acidifying H⁺ ions on soil particles. The carbonate compounds then react with the replaced H ions to form water and carbon dioxide, thereby decreasing the proportion of H ions in the soil and raising soil pH. Calcium alone does not increase soil pH, so gypsum (CaSO₄), CaCl₂, CaNO₃, and other soluble Ca products are not recommended for addressing soil acidity issues.

Lime applications are often considered to be one of the most important management practices in a productive pasture system. Research conducted in Tillamook and Lane counties in Oregon showed a yield increase of 1,000 and 3,000 lb forage/acre, respectively, when lime was top-dressed at a rate of 2 ton/acre (Rogers, 1995). The effects of a lime application may last only 2 or 3 years. Therefore, plan to apply lime regularly to maintain forage quality and yields.

Lime applications are costly, and growth response to lime may take between 6 months to a year. To reduce yearly cost, apply lime to one or two fields each year. Avoid spreading a small amount of lime over a large number of fields, as applications of less than 0.5 ton/acre may be too small to significantly increase soil pH. Think of lime as an “investment” that will pay back over many years each time livestock graze and with each hay or silage harvest.

Lime application recommendations are based on SMP buffer test results. Follow the guidelines in the soil testing section of this guide (page 3) to determine the appropriate soil sampling depth for your specific pasture conditions.

Apply lime to grass and grass/clover pastures if the soil pH is below 5.5. Use the soil test SMP buffer value and Table 2 to determine the amount of lime required. Note that lime application rates are reduced for established fields to avoid smothering plants with the lime material.

The lime recommendations in Table 2 are based on a target soil pH value of 5.8. For fields with less acid-tolerant species, consider using the upper end of the recommended lime application rate. If it is cost-prohibitive to add the recommended amount of lime, even a lower lime rate of 1 to 2 ton/acre will be beneficial.

To ensure adequate soil pH for several years and to avoid the

need for a top-dress lime application, a reasonable approach is to raise soil pH to 0.2 to 0.3 pH unit above the recommended minimum pH level in Table 1. To achieve this goal, increase lime application rates by approximately 0.5 ton/acre above the recommendations in Table 2.

For new seedings established with tillage, preplant application of lime to bare soil is the most effective application method and produces the fastest response. The material can be thoroughly mixed into the soil ahead of planting so that it has time to react and change the pH throughout the tillage depth. In addition, a large amount of lime can be added during field cultivation, thereby quickly raising a low soil pH to desired levels.

For existing pastures or no-till pastures, top-dress lime before fall rains begin and soils become muddy and waterlogged. During the first winter, lime will move only about 1 inch below the soil surface.

When top-dressing, apply no more than 2 ton/acre of the appropriate lime source to avoid smothering or injuring plants (Table 2). Top-dressed lime applications above 2 ton/acre will produce little or no additional soil pH or crop response (Rogers, 1995).

Avoid grazing livestock on recently limed fields, as lime materials can cause eye injury and respiratory issues. To avoid this risk, producers often delay grazing until the spring following a lime application.

Calcium (Ca) and magnesium (Mg)

Calcium is needed by plants to support cell wall structures, while Mg is needed for chlorophyll and protein synthesis. Calcium and Mg usually exist in the soil in adequate quantities when soil pH is above 5.5. If the Ca soil test is below 1,000 ppm (5 meq Ca/100 g of soil) and soil pH is above 5.0, add 1 ton lime/acre.

Table 2. Lime application rates for grass or grass/white clover pastures.¹

If the SMP buffer test for lime is ²	At seeding	Established field
	Apply this amount of lime and incorporate (t/a)	Top-dress this amount of lime (t/a)
Below 5.5	4 to 5	2
5.5 to 5.8	3 to 4	2
5.8 to 6.1	2 to 3	2
6.1 to 6.5	1 to 2	1 to 2
Above 6.5	0 to 1	0 to 1

¹Liming rate is based on 100-score lime, which is an index of calcium carbonate content, moisture, and fineness. For more information about lime materials and lime score, see EM 9057, *Applying Lime to Raise Soil pH for Crop Production (Western Oregon)*.

²OSU lime recommendations are calibrated specifically for the SMP buffer. Recommendations have not been established for Sikora or other buffer pH methods.

Maintaining sufficient levels of Mg in the soil is especially important in pasture systems to prevent grass tetany, a livestock disease caused by Mg-deficient forage. When soil requires lime and is low in Mg (less than 100 ppm or 0.8 meq Mg/100 g of soil), use 1 ton/acre dolomitic lime as a source of both Ca and Mg. Dolomitic lime and ground limestone have about the same ability to neutralize soil acidity. If lime is not needed and Mg levels are low, apply K-Mag (21% K, 10% Mg, 21% S) at a rate of 500 lb K-Mag/acre. For more information on managing soils to prevent grass tetany, see the sidebar “Grass tetany” or visit “Spring Pastures—Grass Tetany and Bloat” at <http://www.ansc.purdue.edu/beef/articles/GrassTetanyBloat.pdf>.

Nitrogen (N)

Nitrogen fertilization is an important practice in pasture production systems, as N is needed by forage crops to support plant growth, protein synthesis, and tillering (see the sidebar “Grass yield and protein response to N fertilizer”). Forage yield and feed quality are reduced when N is insufficient, while excessive N can result in forage nitrate toxicities, nitrate leaching, and production of forage in excess of what can be consumed by grazing animals. Nitrogen deficiencies in pastures often can be detected visually. The majority of the stand will appear pale green, with urine and manure areas remaining dark green.

New pastures

For new pasture stands, an application of 20 to 25 lb N/acre is recommended at seeding. Fertilizer N can be broadcast or banded approximately 1 to 2 inches below the seed. If fertilizer is banded, application rates

Grass tetany

Grass tetany, also called hypomagnesemia or low blood serum magnesium, is characterized by an uncoordinated gait, convulsions, coma, and animal death. It is primarily due to low dietary Mg but can also be caused by a certain combination (ratio) of minerals in the diet. Several factors associated with fertilizing practices can lead to grass tetany in grazing livestock.

Soil conditions:

- Soils low in Mg lead to forages low in Mg.
- Rapid plant growth after N fertilizer application can reduce plant Mg concentration.
- Excessive K fertilization leads to high K concentrations in forage, which can reduce Mg concentrations.

Forage conditions:

- Forage Mg percentage is an indicator of tetany risk:
 - *Tetany-prone*: less than 0.12 percent Mg
 - *Marginal*: 0.12 to 0.18 percent Mg
 - *Safe*: 0.2 to 0.25 percent Mg
- A forage tetany ratio greater than 2.2 is not safe for livestock consumption. This ratio is calculated as: $(\%K/39) / [(\%Ca/20) + (\%Mg/12.1)]$

Avoid these conditions by following recommendations for Mg, N, and K fertilizer applications. Delay K fertilization until after the early-spring tetany period. Avoid grazing animals with high Mg requirements, such as cows in early lactation, on pastures that might contribute to grass tetany. To be safe, add supplemental Mg to the ration or to a mineral block.

Grass yield and protein response to N fertilizer

Grass responds to applied N by increasing dry matter yield and protein. Forage protein requirements differ, depending on the type of livestock and its age/maturity. Forage analyses for crude protein can be used to adjust the N fertilizer application rate to meet site-specific forage quality goals.

Figure 1 demonstrates the relationship between N fertilizer rate, grass yield, and protein. At low rates of N fertilizer input, grass yield increases, while protein remains low. Each increment of additional N fertilizer increases yield by a smaller amount (diminishing returns). When grass no longer responds to N input with increased yield, the added N contributes to an accelerated rate of increase in grass protein.

Although grass in this field trial was not grazed, the growth stage harvested (late vegetative growth; 15- to 18-inch height) and the harvest interval (30 to 40 days) was similar to that recommended for grazing.

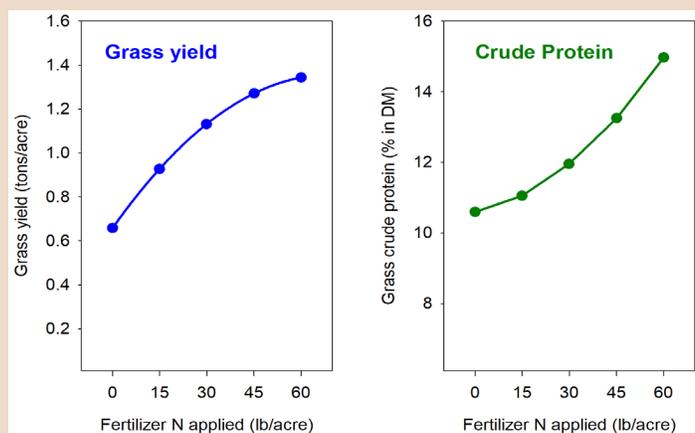


Figure 1. Nitrogen fertilizer increases yield and crude protein in tall fescue harvested at the late vegetative growth stage. Granular N fertilizer (34-0-0) was applied at 0 to 60 lb N/acre after each harvest, a few days prior to sprinkler irrigation. Puyallup, WA, Puyallup sandy loam soil, 3 percent soil organic matter. Adapted from Sullivan, et al., 2002.

should not exceed 100 lb N + K₂O/acre to avoid seed germination issues caused by salt burn.

Established pastures

For established fields, factors such as plant species, forage yield potential, and time of year influence the optimal amount of N required by the pasture crop to produce high-quality and high-yielding forages. See the following guidance to understand how each of these factors affects N use in forage pastures.

Plant species

Forage pastures are typically composed of high-yielding grasses (e.g., annual ryegrass, perennial ryegrass, orchardgrass, tall fescue) and legumes (e.g., white clover, subclover and other annual clovers, red clover, annual or hairy vetch, birdsfoot trefoil) or a combination of the two. High-yielding grasses will readily absorb plant-available forms of N (nitrate-N and ammonium-N). Low-yielding grasses, including bentgrass, velvetgrass, and rattail fescue, have naturally low forage yield and quality potential. Thus, they have a lower requirement for N than high-yielding species.

The presence of legumes in a pasture (Figure 2) reduces the amount of N fertilizer needed to support forage production. Legumes can produce their own N through the process of biological N fixation. *Rhizobium* or *Bradyrhizobium* bacteria infect legume roots, and the resulting root nodules convert N₂ gas from the atmosphere to ammonium-N compounds that can be used by the plant. An example of the N contribution of legumes is shown in Figure 3.

Although most pasture fields have naturally abundant *Rhizobium* bacteria, naturally occurring bacteria often are less efficient than those in commercially available inoculum. Thus, inoculation of legume seed is recommended when legumes are planted.

When excessive amounts of N are available, N fixation is reduced, and legumes behave like grasses by using N from the soil instead of fixing N₂ from the atmosphere. Applying excessive N to a mixed grass/legume stand will also shift the stand composition toward grass species, resulting in lower forage quality and increased N fertilizer requirement over time.

Realistic yield potential

Effective N management practices in pasture systems are based on realistic estimates of forage yield for individual fields. Each pasture has an upper limit to how much yield can be achieved. Yield potential is influenced by soil texture, soil depth, drainage, forage type, precipitation, temperature, weed pressure, manure application history, and irrigation practices. For more information, see Appendix 2 (page 13).

Nitrogen fertilizer response of mixed grass/legume stands

Nitrogen fertilizer application rates should take into consideration the species and density of grasses and legumes present. Forage stands that contain significant amounts of legumes require less N from fertilizer.

Figure 2 shows that relatively high forage yields can be produced with minimal N fertilizer inputs when legumes are present. In Figure 2, the same dry matter yield was produced with:

- Grass alone, with a fertilizer rate of 125 lb N/acre
- Grass/legume mix with no N fertilizer applied

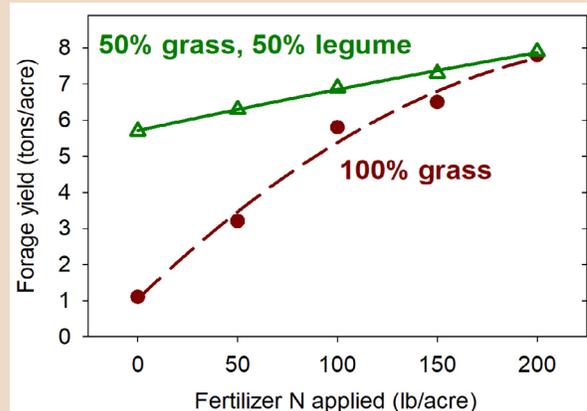


Figure 3. Forage dry matter yield response to N fertilizer in irrigated grass/legume pastures. Pastures were grazed by beef cattle three or four times annually. Approximately half of the annual forage dry matter yield was produced by a hay crop. Data collected at field sites near Ogden, UT. Adapted from Koenig, et al. (2002).

100% grass



75% grass/25% legume



50% grass/50% legume



25% grass/75% legume



Figure 2. Visual guide for grass:legume ratio in pasture. Legumes contribute plant-available N, so N fertilizer applications can be reduced as the percentage of legume increases.

Photos: Amber Moore, © Oregon State University

Time of year

Nitrogen application should be coordinated with appropriate temperatures, moisture availability, and the need for an increase in forage yield. Nitrogen applications are not recommended in November and December, as N applied to cold, wet soils in winter can be leached beyond the root zone or washed off the fields in runoff before slow-growing plants can use the fertilizer.

Winter to early spring (January to April). Proper N management is especially important during winter and early spring, as adequate N is needed to support rapid plant growth between April and June. Local temperatures impact the start date for winter/early-spring fertilization. For example, pastures in the warmer south-coast region may respond to N fertilizer applied in January or early February, while pastures in the cooler Cascade

regions may not respond to N fertilizer applications until mid-March or early April. An N application timing schedule specific to pastures in subregions of western Washington and western Oregon is illustrated in Figure 4.

PASTURE NITROGEN CALENDAR												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
North coast		→	→			→			→			
South coast	→						→		→			
Puget Sound, I-5 corridor, inland western WA		→	→			→			→			
Willamette Valley		→		→					→			
Cascade foothills			→			→			→			

Figure 4. Pasture N calendar. Additional applications for irrigated pastures are indicated by dashed lines. This calendar is only an approximation, based on typical climatic conditions of pasture production subregions in western Oregon and western Washington. Other site-specific factors should be considered when determining the exact timing of N fertilizer application, as described in the “Time of year” section.

T-Sum method for early-spring forage production on grazed pastures

For well-managed pastures containing grass species, the T-Sum method can be used to estimate the appropriate date for the first N fertilizer application. T-Sum 200 is an accumulation of growing degree days (or heat units) on a Celsius degree basis, starting on January 1. See Appendix 3 (page 14) for T-Sum calculation details.

The T-Sum 200 date falls between late January and early February, depending on the year and location. Typical early-spring N fertilizer application dates based on T-Sum are:

- **Western Oregon** (Willamette Valley): January 25 to February 15
- **Western Washington** (30-year average): Aberdeen (February 8), Centralia (February 10), Buckley (February 14), Mt. Vernon (February 16)

Nitrogen applied at T-Sum 200 can increase the amount of early forage produced for grazing livestock. Field research in Coos, Douglas, Tillamook, and Benton counties (Oregon) demonstrated an average increase in harvestable dry matter of 750 to 1,000 lb/acre from a T-Sum 200 application of 60 lb N/acre (Pirelli, et al., 2004; Peters and Hart, 2007). The recommended N application rate at T-Sum 200 is 40 to 60 lb N/acre, depending on the grass yield potential.

The T-Sum 200 method for early N application is not appropriate for all pastures, as a pasture with a poor stand may have growth-limiting factors that would prevent plant growth response to an early N application. Below are

characteristics of a field that would be well suited for use of the T-Sum 200 method:

- *Fields containing grass or a grass/legume forage mix*, such as tall fescue, orchardgrass, or perennial ryegrass combined with a clover. Bentgrass and legume-only pastures are not ideal for early-spring N application.
- *Fields that are not overgrazed in the fall*. Adequate leaf area in the fall ensures that plants have sufficient carbohydrate for winter survival and early-spring growth. For optimal response to T-Sum fertilization, 3 inches of forage should remain throughout the winter.
- *Well-drained fields free of standing water*. Wet, poorly drained soil does not permit forage growth.
- *The field is accessible to equipment for N application in January/February*.
- *The field has enough plant growth to support grazing in March or early April* without damaging the grass stand or the field. Three inches of forage should remain after spring grazing.
- *Soil pH and fertility are properly managed*, following recommendations provided in this publication.
- *Soil compaction and other production factors are not greatly limiting crop growth*.

In summary, the N application at T-Sum 200 can be used in western Oregon and western Washington to increase forage yield on fields that are well positioned to respond to an early application of N.

Another site-specific factor that impacts winter/early-spring fertilization is precipitation and drainage. In western Oregon and western Washington, heavy rainfall may cause pastures to become saturated. On poorly drained soils, N applications must be delayed until there is no standing water and the soil water table has dropped enough to allow safe use of fertilizer application equipment.

See the sidebar “T-Sum method for early-spring forage production on grazed pastures” (page 7) for more information.

Late spring to early summer (April to July).

Intensively grazed pastures that are expected to produce a high level of forage through June should receive additional applications of N. For grass pastures, N fertilizer applications should follow each cutting or major grazing event, so multiple applications may be required. For grass/legume pastures, N fertilizer applications may be less frequent.

After mid-May, apply N only if moisture is sufficient for additional growth. July applications are recommended only for irrigated coastal pastures.

Late summer to fall (August to September). In western Oregon and western Washington, the pasture growing season begins when fall rains begin. Do not apply fall N if adequate rain does not fall until late October or if the air temperature drops below freezing in October, as these conditions will greatly limit fall tillering and growth.

Many growers apply fertilizers to dry soil and note that the granules disappear before any rain falls, raising concerns that fertilizer N may have been lost to the atmosphere through ammonia volatilization. Although a small amount of fertilizer N may be lost this way, most

of the “missing” N fertilizer has been dissolved by dew and has moved into the surface soil.

Although limited use of N fertilizer in the fall can stimulate forage regrowth after fall rains, it is important to recognize that too much fall N can lead to vigorous plant growth that reduces winter hardiness. As temperatures decline in the fall, plants produce a type of “antifreeze” called proline. This antifreeze accumulates in every living plant cell, but only when excessive N is not available. Thus, excess N inhibits plants from preparing for winter, leaving them susceptible to injury or death from the first major cold event.

Other factors

Other factors may increase N requirements above recommendations in this publication, including low soil organic matter content (less than 2 percent) and harvesting of forage for hay. Factors that can decrease N requirements below recommendations include a history of manure or biosolids applications, N recycling from intensive grazing, high soil organic matter content (greater than 4 percent), and anything that limits plant growth (weed pressure, high water table, acidic soil conditions, extreme weather conditions, etc.).

Recommended N rates

Annual N recommendations are provided in Table 3 to give a general idea of the amount of N needed for optimal growth. However, because so many factors influence N management in pasture systems, you should expect to adjust these values as needed to reflect your specific situation. The N recommendations in Table 3 are based on those found in *Pasture and Grazing Management in the Northwest* (PNW 614). For information on estimating yield potential, see Appendix 2 (page 13).

Table 3. Annual nitrogen recommendations for grazed pasture systems in western Oregon and western Washington, based on realistic yield potential and plant composition.

	Yield potential of the field			
	1–2 ton/acre ¹	2–4 ton/acre	4–6 ton/acre	6–8 ton/acre
	N recommendation (lb N/acre)			
100% grass	50	75 ²	100 to 150 ²	150 to 200 ²
75% grass/25% legume	25	50	75 to 100 ²	100 to 150 ²
50% grass/50% legume	0	25	50	75
25% grass/75% legume	0	0	25	50

Adapted from *Pasture and Grazing Management in the Northwest* (PNW 614)

¹T-sum applications are not economical for low-yielding pastures.

²For higher yielding pastures with grass-dominated plant species, split the total N rate into two or three separate applications following guidelines in this publication and the N application calendar in Figure 4 (page 7).

Nitrogen fertilizer source

Common granular N fertilizers for pasture include urea (46-0-0) and ammonium sulfate (21-0-0-24S). Common liquid fertilizers include urea-ammonium nitrate (32-0-0) and ammonium polyphosphate (10-34-0).

Some of the N from some granular or liquid N fertilizers can be lost as a gas (ammonia; NH_3) during the first week after N fertilizer application to pasture. This type of N loss is of concern only with urea and fertilizer mixtures that contain urea (e.g., urea-ammonium nitrate). Fertilizers that do not contain urea (e.g., ammonium sulfate) do not lose a significant amount of N as NH_3 gas. Losses of N as ammonia gas can be high (10 to 30 percent of N applied). However, on western Oregon pastures, losses typically are less than 5 percent of N applied. Irrigation or rain (more than 0.5 inch) within a few days after application moves urea into the soil and reduces the amount of N lost as gas.

Newer N fertilizer products include additives to reduce ammonia loss following fertilizer application. Products such as polymer-coated urea or urea treated with a urease inhibitor (e.g., Agrotain) can reduce

ammonia loss from surface-applied urea. However, they are unlikely to routinely prevent enough NH_3 loss to justify their extra cost. The risk of NH_3 loss is highest with early-fall N fertilizer applications to dry soil, so fertilizer additives that reduce ammonia loss are most likely to provide benefit under these conditions.

Nitrogen fertilization is the most important driver for soil acidification (decreased soil pH) in pastures. The most acidifying fertilizers supply all of their N as ammonium-N. Fertilizers that supply some N as urea are less acidifying per pound of N. Manure, compost, and other organic N sources are generally less acidifying than commercial N fertilizers, as they contain mostly organic N and also supply basic cations (Ca, Mg, K, and sodium). *Soil Acidity in Oregon: Understanding and Using Concepts for Crop Production* (EM 9061) provides a quantitative comparison of acidity produced by various N fertilizer materials in soil.

See the sidebar “Supplying nutrients to pasture with manure or municipal biosolids” for additional information about using organic materials to supply N for pastures. Not all “organic” sources are allowed under certified organic production rules (e.g., National Organic Program). Contact your organic certifier regarding appropriate organic sources.

Supplying nutrients to pasture with manure or municipal biosolids

Animal manures or municipal biosolids can be used to supply a portion of the nutrients needed for pasture. Both biosolids and manure supply N, P, Ca, Mg, S, and micronutrients. Manure also provides K, but biosolids do not contain significant amounts of K.

Manure and biosolids vary in nutrient composition depending on water content, added materials (e.g., bedding), and processing (composting or “aging”). A recent nutrient analysis of your manure or biosolids source is always recommended. General “book values” for manure nutrient content can be found in *Fertilizing with Manure and Other Organic Amendments* (PNW 533). You can read more about municipal biosolids in *Fertilizing with Biosolids* (PNW 508).

Manure or biosolids contain both rapidly available N (in ammonium form) and slowly available N (in organic form). Relative to urea, biosolids and manure are generally 30 to 50 percent as effective per unit of total N applied during the first year after application (Sullivan, et al., 2000; Cogger, et al., 2001). Thus, biosolids or manure applied at 100 lb total N/acre will supply 30 to 50 lb plant-available N/acre. Most of the plant-available N from manure or biosolids is utilized by the first two or three forage harvests after application.

Unlike mineral fertilizers (e.g., urea), biosolids or manure can be applied in fall and will stimulate pasture growth early in the following spring. Fields for fall or early-spring manure or biosolids application must be managed carefully to prevent runoff.

When any N source (manure, biosolids, or urea) is applied, soil becomes more acidic with time. The acidity results from the nitrification process (conversion of ammonium to nitrate-N). At a given rate of plant-available N application, biosolids and urea have a similar soil acidification effect. Manure is slightly less acidifying than urea.

Only a few manures (e.g., dairy solids from lagoons or mechanical solids separators) are suitable for high-rate application to supply P and K prior to reseeding a pasture. These manures generally contain 1 to 2 percent total N and have a C:N ratio of 15 or greater. Most other manures or biosolids will supply too much N if applied at rates needed to supply P and K.



Photo: Dan Sullivan, © Oregon State University
Figure 5. Application of dairy slurry at a research trial (Sullivan, et al., 2000), Buckley, WA.

Phosphorus (P)

Adequate levels of soil P are important for root production in grass and clover pastures. Phosphorus applications favor legumes; therefore, they can be used to support legume growth in a grass/legume pasture.

Visual symptoms of pastures with inadequate P include limited root mass and depth (which can be difficult to quantify without a comparison), stunted aboveground forage (short, small leaves), and a light to dark purple color on leaves and/or stems of both grasses and clovers.

Because P binds to the soil, it can accumulate in the soil and does not need to be applied as often as N. Phosphorus accumulation can be documented with soil testing.

Recommendations for P application rates based on the Bray P soil test are provided in Table 4.

For new seedings, P fertilizer may be banded with the seed or broadcast and incorporated prior to seeding. Band 1 to 2 inches to the side or below the seed to avoid burning newly emerging seedlings.

For established fields, P can be applied in either the fall or spring. Fall P applications can be advantageous, as pasture grasses are developing their primary growing points and roots at this time. Spring applications can also be useful, as cool spring temperatures and acidic soil conditions reduce P solubility, thus inhibiting new root development and P uptake by plants. In either case, apply P to established pastures before growth begins.

Potassium (K)

Potassium supports water transport and metabolic function in pasture plants and, therefore, is essential for optimal growth of clover/grass pastures. Potassium is particularly important for legume species, as grasses compete with clovers for K.

High-producing pastures can rapidly decrease soil test K values. Potassium deficiency is indicated by light-colored spots around the margins of clover leaves and yellow to brown coloring of grass leaf tips. However, growth responses to K fertilizer often can be obtained before deficiency symptoms are detected.

Table 4. Phosphorus application rates for pastures.

If the Bray soil test for P is (ppm)	Apply this amount of phosphate (P ₂ O ₅) (lb/a)
0 to 15	100 to 60
15 to 30	60 to 0
Above 30	0

If you apply K-rich animal manures to your pasture, be mindful of the potential for excessive levels of K, which can lead to grass tetany issues for grazing animals.

Potassium fertilizer guidelines are found in Table 5. For new pastures, broadcast K and incorporate into the seedbed prior to seeding. If the soil test is below 125 ppm, band an additional 20 lb K₂O at the time of planting. Potassium can be banded with N and P. If fertilizer is banded, application rates should not exceed 100 lb N + K₂O/acre to avoid seed germination issues caused by salt burn. At least 1 inch of soil should separate the seed and fertilizer. Note that K fertilization at planting will not meet the need for K in subsequent years.

For nonirrigated established pastures, apply K in the fall or spring, following recommendations in Table 5. In high-yielding irrigated pastures, split applications (late spring and midsummer) are recommended to reduce K-induced Mg deficiencies that may lead to grass tetany. For more information, see the sidebar “Grass tetany” (page 5) or “Spring Pastures—Grass Tetany and Bloat” (<http://www.ansc.purdue.edu/beef/articles/GrassTetanyBloat.pdf>).

Sulfur (S)

Plants take up S in the form of sulfate (SO₄). For new fields, broadcast or band sulfate-S fertilizers at a rate of 15 to 25 lb S/acre. On established fields, top-dress S at a rate of 20 to 30 lb S/acre annually or 40 to 50 lb

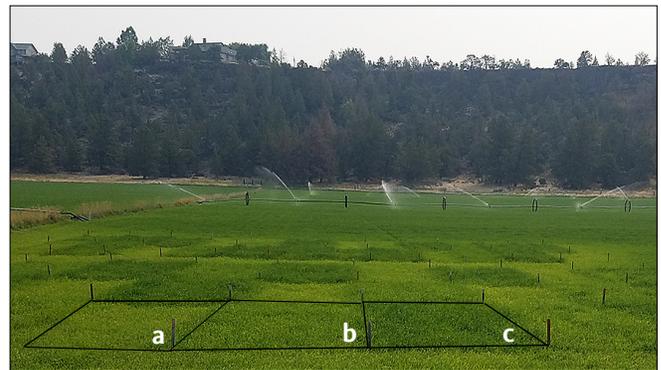


Photo: Mylen Bohle, © Oregon State University

Figure 6. Experimental plots compare N and S treatments: (a) no N or S application, (b) 60 lb N/acre with no S, and (c) 60 lb N/acre with S added. Orchardgrass in Terrebonne, OR.

Table 5. Potassium application rates for pastures.

If the soil test for K is (ppm)	Apply this amount of potash (K ₂ O) (lb/a)
0 to 125	150 to 100
125 to 200	100 to 70
Above 200	0

S/acre every 2 years. Sulfate-S fertilizers can be applied in fall or spring with good results. Figure 6 (page 10) shows plant response to S application.

Nitrogen fertilizer applications without adequate S fertilization can result in rapid decline of the clover component of a grass/clover mixture. An N:S ratio greater than 10:1 in a forage tissue analysis may indicate S deficiency. Sulfur-deficient plants respond rapidly to sulfate-S application. During the rainy season, plants can recover from S deficiency in 3 to 4 weeks following a broadcast sulfate-S application.

Fertilizers containing sulfate-S include ammonium sulfate (24% S), gypsum (16 to 19% S), and potassium magnesium sulfate (21% S; often called K-Mag or Sul-Po-Mag). Fertilizer dealers also offer fused prills of urea-ammonium sulfate, such as Urea-Sul (33% N, 11% S). Sulfate fertilizers are not very water soluble, so they typically are not fertigated. Liquid fertilizer N:S mixes typically contain thiosulfate (S_2O_3); the most common is ammonium thiosulfate (12% N, 26% S).

Sulfur can also be supplied as elemental S. Elemental S acidifies soil and slowly releases plant-available sulfate-S. To be an effective S source, elemental S must be applied well ahead of crop demand or be of very fine particle size (less than 0.1 mm diameter; Rasmussen and Kresge, 1986).

Selenium deficiencies can be triggered by S applications. See PNW 614, *Pasture and Grazing Management in the Northwest* (chapter 3, “Soils, Fertility, and Nutrient Management for Pastures”) for more details.

Boron (B)

Legumes have a higher B requirement than grasses, as B is used to support root nodulation in legume crops. Too much B can be highly toxic to plants and animals. Therefore, apply B only if soil tests indicate a need. Do not exceed suggested rates.

If the soil test for B is below 0.7 ppm, an application of 2 to 3 lb B/acre is recommended. Spring applications are preferred because B, like N and S, can leach. However, fall applications are also appropriate.

To avoid acute B toxicity issues, never band B-containing fertilizer materials. Distribute B evenly over the field. Solubor (sodium borate) is a suitable source of B. It can be applied evenly over a field via spray application. Dry B fertilizer can be mixed with other fertilizers. However, be aware that crop damage can occur if too much B is added or if B is not evenly dispersed throughout the fertilizer blend.

Selenium (Se)

Selenium is not an essential plant nutrient, but it is an essential nutrient for animals. A variety of methods can be used to provide Se to animals, including applications of Se-enriched fertilizers to pastures and forage crops. To learn more about strategies for providing Se to grazing animals via Se fertilization, see *Selenium Supplementation Strategies for Livestock in Oregon* (EM 9094).

Molybdenum (Mo)

Molybdenum is used by legumes to facilitate N fixation. Existing Mo in the soil becomes more plant-available as pH increases in acidic soils. Therefore, liming to maintain soil pH above the recommended threshold (pH 5.5 for most pasture species) is an effective way to ensure adequate Mo supply.

If soil acidity can't be overcome with lime applications, and tissue Mo is below 0.3 ppm, legumes may benefit from an application of 0.4 lb Mo/acre. Molybdenum can be applied in a foliar spray as sodium molybdate.

Keep in mind that an application of Mo will correct only Mo deficiency issues. It will not correct Mn toxicity, Al toxicity, P deficiency, Ca deficiency, Mg deficiency, or other issues caused by acidic soil conditions. Therefore, liming is the best way to correct Mo deficiency issues, as it will correct these related problems at the same time.

Molybdenum toxicities in livestock, or molybdenosis, can occur when Cu:Mo ratios in forage tissue are below 2:1. While uncommon, this problem can occur on fields low in Cu that receive excessive Mo applications. If you suspect Mo toxicities, monitor forage concentrations of Mo and Cu. To learn more, see Meyer, et al., 1999.

Appendix 1. Plant Growth Phase, Grazing Management, and Nutrient Management

Although growth rates are influenced by temperature, moisture, solar radiation, and overall soil fertility, grazing management has a profound impact on pasture production. Plant growth phases are used to describe pasture growth and the potential for forage production (Figure 7). Phase I (lag phase), Phase II (vegetative or log phase), and Phase III (maturity or senescence phase) describe the stages of growth and their impacts on grazing and forage production.

In **Phase I**, plants grow slowly because they lack sufficient leaf area for photosynthesis. In western Oregon and Washington, a pasture with less than 3 inches of plant height is considered to be in Phase I and should not be grazed until growth exceeds 3 inches. Keeping pasture plants in Phase I greatly reduces their response to nutrient application. It also can have negative effects on animals, such as grass tetany in the spring or weight loss due to low forage intake. If the pasture is constantly overgrazed throughout the growing season, it will not transition out of Phase I into more advanced growth phases.

Phase II (3 to 12 inches of growth) is desired in pastures. Plants grow most rapidly and efficiently in this stage. When grazing animals reduce pasture height to 3 inches, move the animals to another pasture with adequate growth. The resulting rest period will allow for regrowth in the first pasture. Managing pastures in this manner, referred to as a rotational grazing system, allows plants to develop sufficient leaf area for efficient use of sunlight. During hot weather, leaving 4 inches of growth will reduce soil temperatures as much as 10°F compared to an overgrazed pasture in Phase I.

It is important to maintain pastures in Phase II during the critical late-summer and early-fall period. Two major plant activities occur during this period: root regeneration and formation of shoots (growing points) for the following year. Overgrazing or excessive forage harvest inhibits root system rebuilding and the formation of shoots for spring growth, resulting in reduced forage production during the next growing season. Allowing plants to store carbohydrates in the fall is also essential for long-term pasture production.

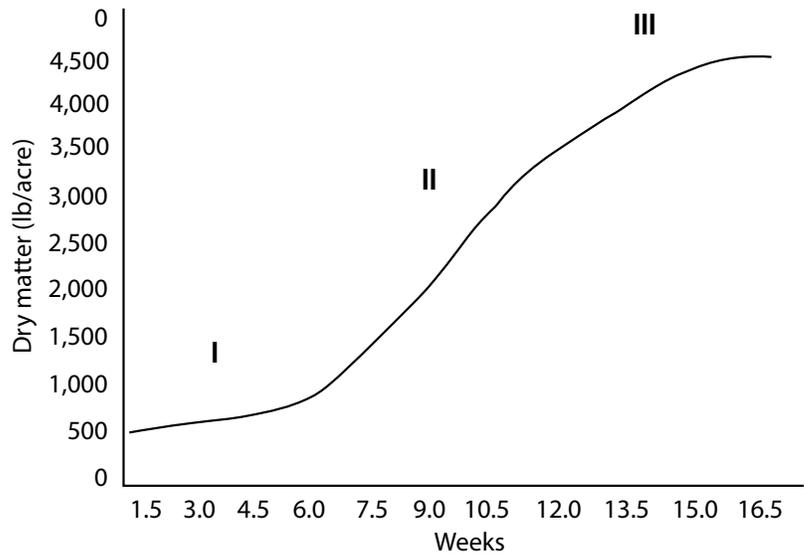


Figure 7. Example of orchardgrass growth phase response to time. Data collected at Monmouth, OR, March to July 1985. Data from G. Pirelli.

Finally, the insulation from taller forage keeps plants growing later in the fall and helps start growth earlier in the spring.

Do not graze plants below 3 inches in late summer and fall, even if the plants are dry and dormant. Grazing below this height will reduce forage response to a T-Sum 200 N application the next year.

Phase III (greater than 12 inches, varying by species and variety) is the reproductive phase. During this phase, plant growth slows, the lower leaves become shaded and die, and the seedhead emerges. Grazing efficiency is reduced due to trampling, the response to nutrient application is reduced, and animal performance suffers.

The most efficient use of Phase III pasture is as conserved forage, such as hay or silage. With the major perennial grass and legume pasture species grown on the westside, regrowth will emerge following a hay or silage harvest, assuming nutrients and water are adequate. Plants will again progress through Phase I and Phase II if conditions allow. The ability to manage pasture species strictly as pasture or in combination with one or more hay or silage harvests is one of the greatest attributes of westside pastures.

Appendix 2. Realistic Yield Estimations

By estimating a pasture's realistic yield, you can determine the amount of N needed to support optimal forage quality and yield. Yield potential is influenced by soil texture, soil depth, drainage, forage type, precipitation, temperature, weed pressure, manure application history, and irrigation practices. Realistic yield estimates are based on the estimated average yield from a 3- to 5-year period.

Estimating forage yield is more challenging in grazed systems than in row crop systems because the forage is not collected at a single harvest event. A variety of methods can be used to estimate forage yield in a grazed pasture. One simple method uses a combination of animal units and bale yield estimates.

The number of animal units can help you estimate the amount of pasture dry matter consumed by grazing animals, based on the amount needed to maintain their body weight. Most grazing animals will digest approximately 2.5 percent of their body weight as feed on a daily basis. In a grazed forage system, grazed yield (dry weight basis) is estimated using the following calculation. (Grey-shaded areas represent required producer inputs.)

$$\frac{\text{no. animals}}{\text{acre}} * \text{animal wt (lb)} * \text{days in field} * 0.025 * \frac{1 \text{ ton}}{2,000 \text{ lb}}$$

= grazed forage yield (ton/acre)

Table 6 shows examples of estimated grazed yield, based on animal type and typical grazing periods in western Oregon and western Washington.

In addition to grazed forage yield, pastures may also be baled for hay during peak growth seasons when forage production exceeds the amount consumed by the animals. Baled yield should be added to grazed yield to determine a pasture's total realistic yield. Baled yield (dry weight basis) can be estimated using the following

calculation. (Grey-shaded areas represent required producer inputs.)

$$\frac{\text{no. bales}}{\text{acre}} * \text{bale wt (lb)} * \frac{100 - \text{moisture content (\%)}}{100} * \frac{1 \text{ ton}}{2,000 \text{ lb}}$$

= baled forage yield (ton/acre)

Table 7 lists examples of estimated baled yield, based on bale size and number of bales harvested per acre.

Other methods of estimating yield include the clipping method, the rising plate method, and the pasture ruler method. These methods are based on relatively direct measurements of plant growth or biomass content over the production season. Therefore, they are more labor intensive but potentially more accurate than the animal yield/baled yield calculations described above. To learn more about these methods, see Hall, 2007.

Table 7. Estimated baled yield (dry matter) in a pasture system that is baled for hay, based on number of bales harvested and bale weight.¹

Number of bales/a	Bale weight (lb/a)		
	70	110	1,400
	Dry matter yield (ton/a)		
5	0.1	0.2	3.0
10	0.3	0.5	6.0
20	0.6	0.9	—
40	1.2	1.9	—
60	1.8	2.8	—
80	2.4	3.7	—

¹Moisture content of forage tissue in the bales is assumed to be 15 percent.

Table 6. Estimated grazed yield (dry matter) in a grazed pasture, based on animal type, number of animals in the field, and number of days on the field.¹

200-lb sheep	Animal type		Days on pasture field			
	1,000-lb beef cattle (animals/a)	1,300-lb beef cattle	15	30	45	60
			Grazed yield (ton dry matter/a/yr)			
5	1	—	0.2	0.4	0.6	0.8
10	2	1	0.4	0.8	1.1	1.5
15	3	2	0.6	1.1	1.7	2.3
20	4	3	0.8	1.5	2.3	3.0
25	5	4	0.9	1.9	2.8	3.8

¹Intake per day is assumed to be 2.5 percent of the animal's body weight.

Appendix 3. Calculating T-Sum in Oregon from Weather Data

T-Sum 200 is an accumulation of heat units (in degrees C) for consecutive days beginning January 1, until a total of 200 is reached. Research shows that certain plants such as cool-season grasses initiate growth at or near this time. A heat unit, or growing degree day (GDD), is the average of the high and low temperature for the day, in degrees Celsius. If the temperature is below 0°C, the heat unit is 0. The formula for calculating a T-Sum heat unit is:

$$\frac{\text{maximum } ^\circ\text{C} + \text{minimum } ^\circ\text{C}}{2}$$

For example, if the high for January 1 is 11.7°C and the low is 4.4°C, the number of heat units for that day is 8.1 (11.7 + 4.4 ÷ 2 = 8.1).

T-Sum calculations are available online from OSU Integrated Plant Protection Center (<http://uspest.org>). You can see degree day accumulation on a regional map or estimate T-Sum for a specific weather station using an online degree day model.

When using an online calculator, specify the following:

- Lower temperature threshold for degree day accumulation (biofix) = 0°C
- Start date: January 1
- Calculation method: Simple average growing degree days

Some online degree day calculators use degrees F; in this case, T-Sum 200 occurs when 360 degrees F have accumulated (1°C = 1.8°F).

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