

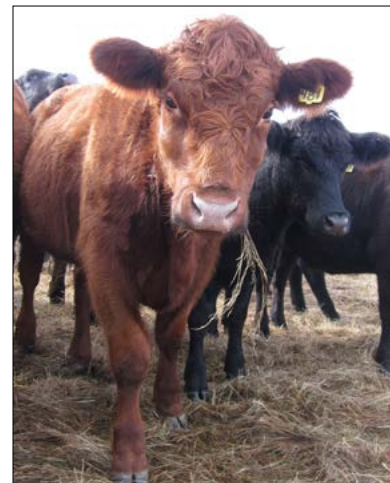


**THE WESTERN OREGON  
AND WASHINGTON  
PASTURE CALENDAR**

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Oregon State University • University of Idaho • Washington State University

# The Western Oregon and Washington Pasture Calendar

Steve Fransen, Gene Pirelli, Marty Chaney, Larry Brewer, and Scott Robbins



**F**orage is the foundation of any successful livestock grazing system. Forage quality and quantity will determine stocking rate, daily gain, reproductive success, and animal health and vigor. Successful forage production depends on climate, soil, crop type, and proper management of both the above- and belowground plant parts.

This publication describes—by climatic zone—perennial pasture plant growth and how management actions can affect growth, both positively and negatively. Optimal management of forages by season is the basis for the Pasture Calendar.

Selecting forage species that are best adapted to your microclimate and learning to manage the growth habits of those species is critical to pasture sustainability (Bedell, 1986). Although much of this basic information has been known for more than a century (Hunter, 1906), it is receiving new attention as modern research and technology help livestock producers develop more sustainable grazing systems.

This publication is separated into several sections. Variables that affect forage production and quality are examined in depth (pages 3–5) and then are integrated and summarized in the Pasture Calendar (pages 9–10). The Pasture Calendar, which is the keystone of this publication, charts forage growth through the year and describes management practices that can influence forage quality and quantity. The appendices provide detailed information on various aspects of forage management.

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# Grass Terminology

**Carbohydrates**—Plant foods, primarily fructosans in grasses and starch in legumes. Fructosans are very sweet, and animals can sense their presence.

**Cell wall constituents**—Lignin, hemicellulose, and cellulose. These materials are created through photosynthesis and sugar metabolism. Cell walls provide the digestible energy for grazing animals.

**Cool-season grasses**—Grass species that begin to grow in the spring and continue growth as long as soil moisture and cool temperatures prevail. Their growth rate decreases during the hot, dry months of summer. Regrowth will begin in the fall if moisture is adequate. In western Oregon and Washington, cool-season grasses account for nearly all pasture grasses.

**Crown**—The transition zone between the roots and the aboveground portions of the plant (Figure 1). This is the zone where carbohydrates are stored and where growing points are initiated.

**Growing point (apical meristem, “bud”)**—The point from which roots, leaves, stems, and seedheads grow (Figure 1). Intercalary meristems are located at the junction of the collar and the leaf blade. They permit rapid regrowth of leaf tissue after grazing or cutting.

**Plant food reserves**—Sugars (carbohydrates) that provide energy for plant growth, regrowth after harvest, and winter survival. In grasses, reserves are stored mainly in the lower stems and also, if present, in the corms. Small amounts of storage carbohydrates are also found in roots. In contrast, legumes store sugars as starch in the crown, stolons, and roots (Figure 14, page 34).

**Rhizome**—An underground stem composed of nodes and internodes (Figure 1). Internodes provide carbohydrate storage, and nodes are the sites for root and shoot development.

**Root**—The underground portion of the plant (Figure 1). Each grass tiller has its own roots. Roots physically anchor the tillers and transport water, nutrients, and essential minerals. They also store small amounts of carbohydrates.

**Stolon**—An aboveground stem composed of nodes and internodes. Internodes provide carbohydrate storage, and nodes are the sites for root and shoot development.

**Stubble**—The remaining plant material after grazing or cutting, generally the 3 to 4 inches above the soil surface. Stubble is one of the main areas for carbohydrate storage, which sustains the plant through periods of seasonal dormancy and reinitiates growth after forage removal.

**Tiller**—The basic unit of the grass plant (Figure 1). A tiller consists of an aboveground stem, including leaves and perhaps a seedhead, and its attached roots below ground. Tillers with seedheads are called reproductive tillers, while tillers that produce only leaves are called vegetative tillers. Each tiller is joined at the base to other tillers to form the grass “plant.” Therefore, the single “plant” that is seen in the pasture is actually a grouping of tillers that share resources such as water, nutrients, and carbohydrates. Each individual tiller lives an average of 1 year, although some can live for 2 to 3 years. An analogy is an apartment building; although the building looks the same from year to year, different tenants move in and out of individual apartments.

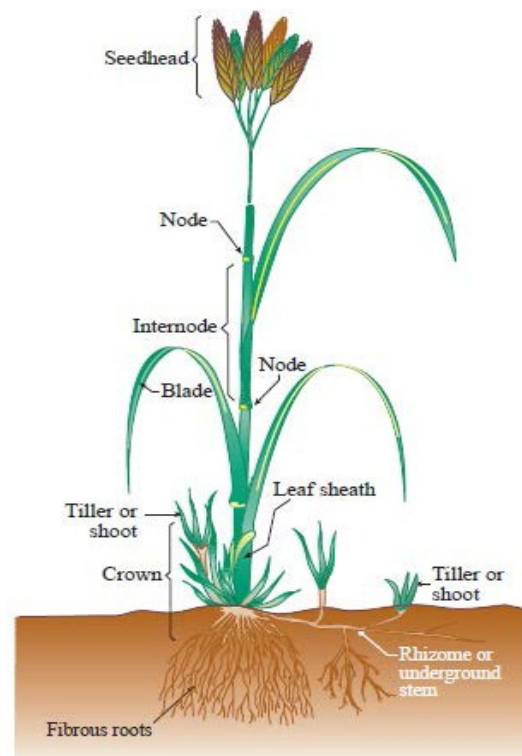


Figure 1. Parts of a grass plant. Used by permission of Iowa State University.

*For more information about grass plant structure and growth, see Appendix 1 (page 33).*

# Factors Controlling Perennial Forage Growth

Forage growth is controlled by environmental, internal plant, and management factors.

## Environmental factors

Major factors include day length, air temperature, and soil temperature. Secondary factors include, but are not limited to, water and nutrients.

### Day length

This factor includes not only hours of light per day, but also intensity and wavelength. In the spring and fall, the tilt of the Earth relative to the sun changes the intensity and wavelength of light. These changes signal the plant to produce new roots and/or new growing points that can develop into reproductive or vegetative tillers. New roots and vegetative tillers are produced in both the spring and the fall. Most reproductive tillers are produced in the fall.

Accumulation of sugar (carbohydrates) and fiber (cell wall constituents) through photosynthesis depends on day length and changes as the season progresses. Levels of plant sugars generally are lowest during summer and are higher in the spring and fall. Plant fiber levels increase as the plant matures.

### Air temperature

Air temperature is directly related to the amount of sunlight intercepted by the earth. However, soil temperature—not air temperature—controls the growth rate of plants (see “Soil temperature”). Since soil temperature is rarely measured, average daily air temperature can be used to estimate soil temperature at about the 4-inch depth.

In general, visible grass growth begins when average daily air temperature (high temperature + low temperature ÷ 2) reaches approximately 42°F. Growth increases rapidly at average temperature of about 52°F and slows at about 62°F. When daily high temperatures exceed 85°F, growth slows significantly without irrigation.

Cool-season grasses will grow at temperatures outside this range, but growth is slow and plants often are stressed. In the spring and fall, air temperatures often fall below the optimum for tiller growth. Roots, however, will grow at slightly lower temperatures, as long as adequate moisture is available. Thus, they often are very active, even when it seems the

plant is not growing. Root growth precedes above-ground growth in the spring and persists later in the fall.

Legumes follow the same general growth pattern, but require higher temperatures to initiate each growth phase, with growth beginning at approximately 52°F (average temperature). Two excellent sources for air and soil temperature data are Agrimet and WSU Ag Weather Net (see “For More Information,” page 49).

### Soil temperature

Soil temperature is also related to the amount of sunlight available. However, soil cools and heats more slowly than air, so it acts as a heat sink, “storing” and “releasing” heat throughout the day and the season. As a result, soil temperatures lag behind air temperatures and can be affected by warm or cold rains. In the spring, the soil is cold and warms less quickly than the air; in the fall, the soil is warm and cools more slowly than the air.

The soil bacteria that make nitrogen (N) available to plants grow best in warm, moist soils. In the spring, when soils are cool, bacteria are less active, so less N is available for plant growth. In the fall, soil bacteria grow rapidly and may produce more N than plants are able to use.

Average daily air temperature can be used as an approximation of daily soil temperature and typically is more readily available. When measuring soil temperature directly, take the measurement approximately 4 inches below the soil surface.

### Water

Water is essential for cooling the plant and for internal movement of nutrients and sugars. Water is absorbed from the soil through the root system. Soil nutrients flow into the plant with the movement of water.

Grasses grow best when the soil is near field capacity (like a moist sponge) and will go dormant when they reach the wilting point. Once they become dormant, grasses require large quantities of water to start regrowing. Because of the lack of water in early fall, plants may show little aboveground growth even when temperatures are in the optimum range.

However, new roots require less moisture and can start growing while the plant top still looks dormant.

### Nutrients

Nitrogen, phosphorus (P), and potassium (K) are the major nutrients required by grass. Sulfur (S), calcium (Ca), and magnesium (Mg) also are essential. In western Oregon and Washington, S, Ca, and Mg usually are in short supply.

Root and bud growth is directly related to availability of these six nutrients. If nutrients are in short supply, plant growth will be reduced in spite of optimum light, temperature, and water conditions. Conversely, excess nutrients can also reduce plant growth. The Pasture Calendar is based on an assumption of adequate soil nutrient status—neither too high nor too low.

Total annual nutrient application should be based on a soil test. West of the Cascades, fall soil nitrate tests usually give the best indication of the success of the N nutrient management program (see EM 8832-E, *Post-harvest Soil Nitrate Testing for Manured Cropping Systems West of the Cascades*).

The timing and amount of nutrient applications will influence uptake and plant tissue nutrient concentrations. Nutrients are best applied in split applications, preceding periods of expected forage growth. For example, applying a majority of the needed nutrients in the spring in one or two applications will fuel rapid growth in spring and summer. Applying excess nutrients in the fall can lead to forage winter-kill or cause pollution through runoff or leaching.

For more information, see Appendix 7 (page 42) and Appendix 9 (page 45).

### Climate zones

The portions of Oregon and Washington west of the Cascade crest extend a great distance in latitude but little in longitude. The Pacific Ocean and Puget Sound act much like heat pumps to keep summer temperatures cooler and winter temperatures warmer than most areas at the same latitude. The Pacific Ocean produces very wet and generally mild winter weather patterns and Mediterranean-like summer drought patterns.

At elevations below 1,000 feet, where temperatures rarely stay below freezing for long periods of time,

spring growth starts early and extends for months as rain showers become less frequent. Summers are dry and generally cool in the northern portion of the region, but warmer in the south. Autumn is shorter than spring and is marked by warm temperatures and increasing rain shower frequency and intensity. Within broad climatic zones, topography and soil differences create numerous microclimates (Figures 4 and 5, pages 6 and 7).

### Internal plant factors and functions

To properly manage perennial grasses, it is essential to know how they grow. The basic unit of a perennial grass plant is the tiller. Each tiller consists of an aboveground stem, including leaves and perhaps a seedhead, and its attached roots. Tillers are joined at the base to form the grass “plant.” Therefore, a single “plant” is actually a grouping of tillers.

Young grass tillers are much like infants. Both need a steady supply of nutrients and protection from stress. The number of tillers formed depends on soil nutrients, moisture, temperature, and previous pasture management.

Grass roots typically do not penetrate as deeply as legume roots, which are more cone-shaped and often are referred to as tap-rooted.

### Annual growth cycle

The majority of new tillers are formed in the fall, when the apical meristem (“growing point”) is formed, and new roots start to grow. At this time, stand density increases, thereby competing with weeds while maintaining a productive pasture.

A secondary period of root growth and tiller establishment occurs in early spring. These new tillers usually are not noticed until midspring, when growth accelerates (Figure 2). Because of this burst

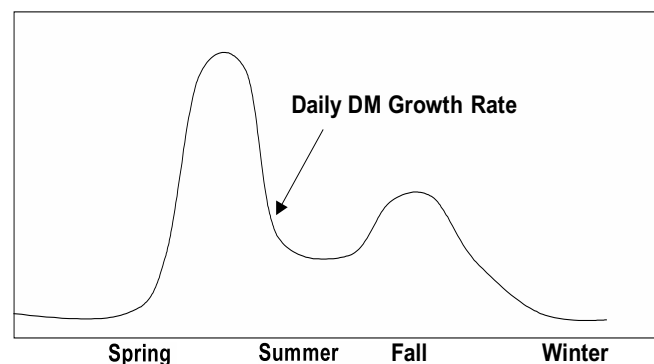


Figure 2. Traditional cool-season grass growth cycle.

of spring growth, this period traditionally has been thought of as the start of the forage or grass year (Fransen et al., 1998).

Based on what we now know about tiller growth (Figure 3), fall should be considered the start of the forage year or the beginning of the Pasture Calendar (Fransen et al., 1998).

In legumes, the bulk of annual growth occurs in late spring to summer, when temperatures have warmed and light competition with grasses is reduced.

### Nutrients for tiller growth

In addition to roots and an apical meristem, each tiller has vertical leaves, which capture sunlight to produce simple sugars, such as glucose and fructose, and more complex carbohydrates, such as fructosans and starch. The bottom 3 to 4 inches of the tillers are the primary location of carbohydrate storage.

During the fall period of peak tiller production, nutrients are supplied from storage at the base of the previous season's tillers. Often, these older tillers are dormant and brown at this time of year. They aren't dead, however, and their storage function is critical. They also provide physical protection for new tillers.

Stored fructosans in grass stubble are sweeter than other carbohydrates, so they are preferred by grazing livestock. Since fructosans are also critical for long-term plant survival, overharvesting grass stubble will degrade the pasture over time.

Eventually, nutrient supplies in the old tillers will be depleted, and new tillers must take over. Following the analogy of the apartment house, if new tenants don't move in as previous tenants move out, rental income will be insufficient and building maintenance will suffer (Fransen and Griggs, 1998).

In legumes, the main storage carbohydrate is starch. Legumes can harvest N from the atmosphere (see Appendix 7, page 42).

## Management factors

Pasture management is the art and science of working within the constraints of environmental factors and plant biology to produce abundant and nutritious forage for livestock. Key management factors include the following:

- Protect roots and soil from damage caused by vehicles or livestock traffic, especially when soils are wet and easily rutted or compacted.
- Maintain prescribed minimum stubble heights throughout the year. If carbohydrate reserves in stubble are lost, tillers will be starved and exposed to weather extremes. Overuse will reduce or delay potential production during subsequent grazing cycles.
- Supply nutrients according to plant needs.
- Provide adequate rest periods for pastures between grazing episodes.
- Have a place to maintain and feed livestock when soils are saturated or when regrowth is inadequate for grazing. Typically, this means providing a sacrifice area and/or alternative forage crops or feed. See Appendix 3 (page 38) and Appendix 10 (page 47).

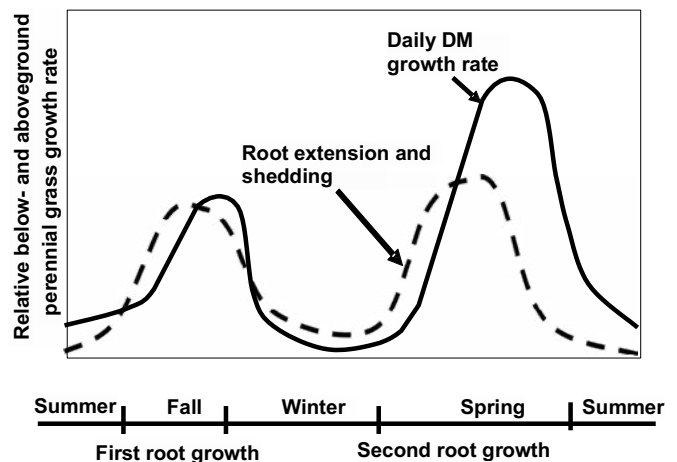


Figure 3. New cool-season grass growth cycle based on aboveground and root growth.

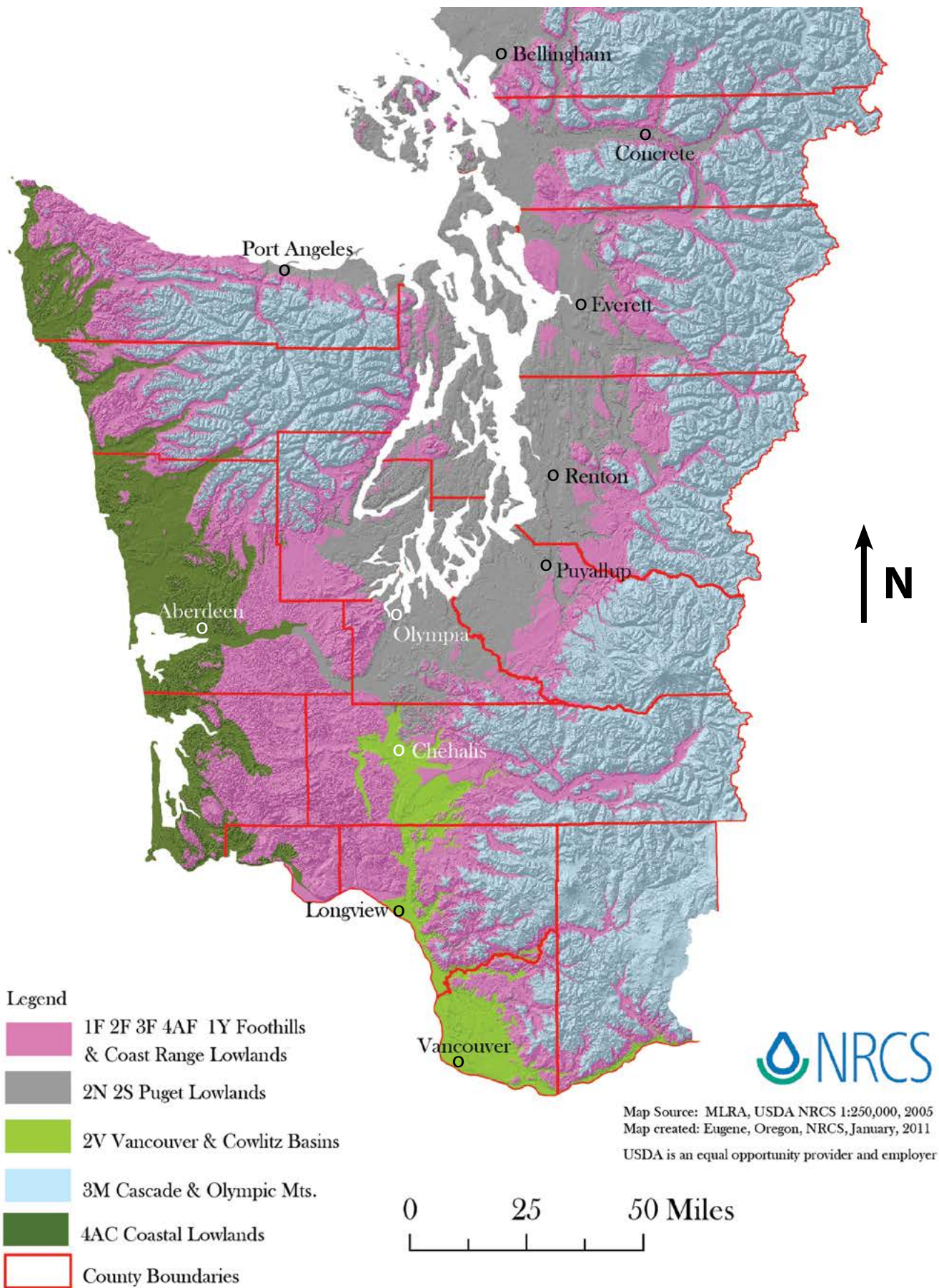


Figure 4. Western Washington forage management zones.

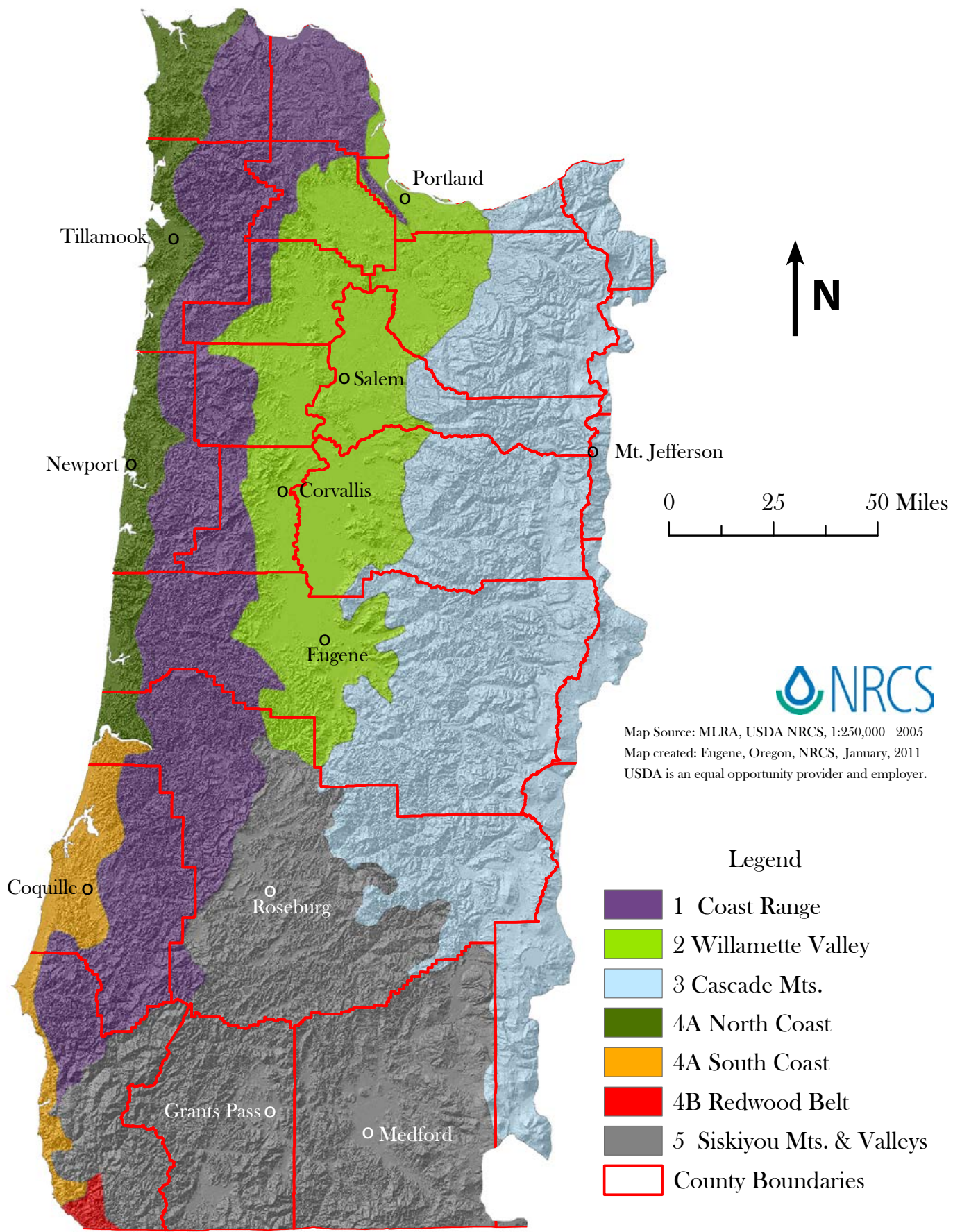


Figure 5. Western Oregon forage management zones.



# Western Washington and Oregon Pasture Calendar

The Pasture Calendar is based on many years of measurement and observation of cool-season perennial forages in western Oregon and Washington. It represents a fundamental shift in pasture management, moving the focus from animals to forage throughout the year.

This approach is based on the hypothesis that certain times of year are more important than others for grass management. Nonetheless, management decisions made during any period will lead to either positive or negative responses during subsequent periods.

As you use the Pasture Calendar, keep in mind that many environmental and internal plant factors, along with management decisions, can disrupt its smooth-flowing nature. Examples include floods, droughts, temperature extremes, plant diseases, or a lack of fencing for rotational grazing. Also remember that the calendar dates given represent an average year. You may need to adjust them slightly for your farm each year.

The Pasture Calendar is intended to be used in conjunction with the Pasture Calendar Summary (Table 1, pages 11–14). The Summary includes information on needed management and actions to avoid,

as well as a description of “what the plant is doing” to increase understanding of the reasons for the recommended actions. Descriptions of each pasture period provide additional important details for each period (pages 15–30).

## The importance of stubble height

Unlike legumes, grasses have very little sugar in their roots; most is stored in the stubble. These sugars are critical for grass regrowth. Grazing below the recommended stubble heights will reduce pasture plants’ ability to regrow. Thus, overgrazing is an expensive mistake that will have costly consequences down the road. Higher stubble heights will also help reduce moss buildup in western Oregon and Washington pastures. *Pay close attention to minimum recommended stubble heights when grazing during any period of the Pasture Calendar.*

To determine average stubble height, take approximately 30 to 50 measurements down to soil level, using a ruler or pasture stick, and find the average. Walk around the pasture in a “Z” or “U” pattern, being careful not to select the tallest or shortest plants.

## Description of Grassland Growth Periods

Period	Name	Description
1	Semidormancy	Recovering from summer dormancy; root growth
2a	Steady regrowth	New green sprigs with much brown remaining; root growth
2b	Steady regrowth	Looks mostly green with little brown; root growth
3	Declining regrowth	Slowing top and root growth; tops may yellow
4	Very slow growth	Plants semidormant; maintenance growth
5	Increasing growth	Plant uses reserves to increase growth of shoots and roots
6a	Rapid growth—cool soils	Plant uses reserves as in Period 5, but at a faster rate
6b	Rapid growth—warming soils	Tops and roots show rapid growth; quality declines without harvest
7	Slowing growth	Top and root growth slows; managed harvest maintains quality
8	Steady growth	Less top growth; root shedding begins
9	Slow growth	Rapid root shedding; drought/heat may start dormancy
10	Dormancy	Dormancy without irrigation; stubble management critical for regrowth

# Pasture Calendar—Western Washington

	Vancouver and Cowlitz Basins		Puget Lowlands		Foothills and Coast Range Lowlands	Coastal Lowlands	Your Farm
Soil moisture status during growing season:	Droughty to adequate	Optimal	Droughty to adequate	Optimal	All	All	
MLRA or CRA:*	2.3, 2.4	2.1, 2.2, 2.3, 2.9	2.6–2.8, 2.10–2.13		1.1, 1.2, 1.3, 1.5, 2.5, 4a.3, 4a.5, 3.1	4a.1, 4a.2	
Forage management zone (Figure 4):	2V	2V	2N, 2S	2N, 2S	1F, 2F, 3F, 4AF, 1Y	4AC	
Month	Growth period (see descriptions on page 8)						
September (1st half)**	1	1	1	2a	2a	2a	
September (2nd half)**	1	1	1	2a	2a	2a	
October (1st half)	2a	2a	2a	2a	2b	2a	
October (2nd half)	2b	2b	2b	2b	2b	2b	
November (1st half)	2b	2b	2b	2b	3	2b	
November (2nd half)	3	3	3	3	3	2b	
December (1st half)	3	3	3	3	4	3	
December (2nd half)	4	4	4	4	4	3	
January (1st half)	4	4	4	4	4	4	
January (2nd half)	4	4	4	4	4	5	
February (1st half)	5	5	4	4	4	5	
February (2nd half)	5	5	5	5	4	5	
March (1st half)	6a	5	5	5	5	6a	
March (2nd half)	6a	6a	6a	6a	5	6a	
April (1st half)	6a	6a	6a	6a	6a	6a	
April (2nd half)	6b	6b	6b	6b	6a	6b	
May (1st half)	6b	6b	6b	6b	6b	6b	
May (2nd half)	6b	6b	6b	6b	6b	6b	
June (1st half)	7	7	7	7	6b	6b	
June (2nd half)	7	8	7	8	7	7	
July (1st half)	9	9	8	8	7	7	
July (2nd half)**	10	9	9	8	8	8	
August (1st half)**	10	10	10	9	8	8	
August (2nd half)**	10	10	10	9	9	8	

\*MLRA = Major Land Resource Area. MLRAs are geographically associated land resource units (LRUs), based on physiography, geology, climate, water, soils, biological resources, and land use.

CRA = Common Resource Area. CRAs are created by subdividing MLRAs by resource concerns, soil groups, hydrologic units, resource use, topography, other landscape features, and human considerations affecting use and treatment needs.

For more information, see [https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/geo/?cid=nrcs142p2\\_053625](https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/geo/?cid=nrcs142p2_053625)

\*\*Depends on soil moisture and precipitation. Water will maintain growth or break dormancy.

# Pasture Calendar—Western Oregon

	Siskiyou Mountains and Valleys	Willamette Valley		Coast Range	North Coast	South Coast and Redwood Belt	Your Farm
		Upland	Bottomland				
<b>MLRA or CRA:*</b>	5.1, 5.7, 5.24, 5.25, 5.28	2.1, 2.2, 2.3, 2.4, 3.1	2.1, 2.2, 2.3, 2.4, 3.1	1.1, 1.2, 1.6, 1.7	4A.1, 4A.2, 4A.3	4A.2, 4B.2	
<b>Forage management zone (Figure 5):</b>	5	2	2	1	4A	4A, 4B	
<b>Month</b>	<b>Growth period (see descriptions on page 8)</b>						
September (1st half)**	10	1	1	2a	2a	2a	
September (2nd half)**	1	1	1	2a	2a	2a	
October (1st half)	2a	2a	2a	2b	2a	2a	
October (2nd half)	2a	2b	2b	2b	2b	2b	
November (1st half)	2b	2b	2b	3	2b	2b	
November (2nd half)	3	3	3	3	2b	2b	
December (1st half)	3	3	3	4	3	3	
December (2nd half)	3	4	4	4	3	3	
January (1st half)	4	4	4	4	4	5	
January (2nd half)	5	4	4	4	5	5	
February (1st half)	5	5	5	4	5	5	
February (2nd half)	5	5	5	4	5	6a	
March (1st half)	6a	6a	5	5	6a	6a	
March (2nd half)	6a	6a	6a	5	6a	6a	
April (1st half)	6b	6a	6a	6a	6a	6b	
April (2nd half)	6b	6b	6b	6a	6b	6b	
May (1st half)	7	6b	6b	6b	6b	6b	
May (2nd half)	8	6b	6b	6b	6b	6b	
June (1st half)	9	7	7	6b	6b	7	
June (2nd half)	10	7   8	7   8	7	7	7	
July (1st half)	10	9	8	7	7	8	
July (2nd half)**	10	10	9	8	8	8	
August (1st half)**	10	10	10	8	8	8	
August (2nd half)**	10	10	10	9	8	8	

\*MLRA = Major Land Resource Area. MLRAs are geographically associated land resource units (LRUs), based on physiography, geology, climate, water, soils, biological resources, and land use.

CRA = Common Resource Area. CRAs are created by subdividing MLRAs by resource concerns, soil groups, hydrologic units, resource use, topography, other landscape features, and human considerations affecting use and treatment needs.

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\*\*Depends on soil moisture and precipitation. Water will maintain growth or break dormancy.

## Table 1. Pasture Calendar Summary

Period	Period name	What the grass is doing	Environmental factors	Management needed	Things to avoid
1	Semidormancy	Very little (if any) forage growth unless irrigated; root growth begins; growing points develop; protein increases; carbohydrates increase and are stored for winter in stem bases.	Rains return; temperatures cooler, especially at night; days shorter; soils are still warm; winter weeds sprout.	Minimum stubble height is critical (3" for bunchgrasses, 2" for sod formers); perform fall soil testing; add lime or nutrients if needed; utilize confinement area as needed; establish new pastures if needed.	Do not graze or mow below minimum stubble height; don't overfertilize with N, as this will interfere with carbohydrate storage and protective dormancy; excess N will also tend to leach or wash away with rain.
2a	Steady regrowth	Forage has new green tillers, but much brown remains visible; roots and growing points continue establishment and growth; carbohydrates still being stored in plant crowns; high protein and carbohydrate levels in forage; highest digestibility of the year.	Day length decreases; fall equinox occurs; rains more regular; soil temperatures cool; air temperatures cool; soil N mineralization increases if moisture is available.	Complete fall soil testing; add lime or nutrients if needed; graze only to minimum stubble height; utilize confinement area as needed; establish new pastures if needed.	Do not graze or mow below minimum stubble height; don't overfertilize with N, as this will interfere with carbohydrate storage and protective dormancy; excess N will also tend to leach or wash away with rain.
2b	Steady regrowth	Forage looks mostly green with little brown; root growth continues; high protein and carbohydrate levels in forage; highest digestibility of the year.	Soil N mineralization rapid; steady rainfall; soils cool further.	Complete fall soil testing; add lime if needed; graze only to minimum stubble height; monitor soils for saturation; remove livestock if needed to avoid compaction; utilize confinement area as needed.	Do not graze or mow below minimum stubble height; don't overfertilize with N, as this will interfere with carbohydrate storage and protective dormancy; excess N will also tend to leach or wash away with rain; avoid soil compaction.

*continues on next page*

## Table 1. Pasture Calendar Summary—*continued*

Period	Period name	What the grass is doing	Environmental factors	Management needed	Things to avoid
3	Declining regrowth	Slowing plant forage and root growth; some root shedding; tops may yellow; protein levels drop; carbohydrate levels remain high.	Short day length slows plant growth; heavy rains; soil nutrients less available to plants; flooding possible on low-lying fields.	Graze only if soils aren't saturated and growth is greater than the minimum stubble height (the grass is very palatable!); utilize confinement area as needed.	Avoid grazing or equipment use when soils are saturated (causes soil compaction and plant damage); avoid overapplication of N, as this will interfere with carbohydrate storage and protective dormancy; excess N will also tend to leach or wash away with rain.
4	Very slow growth	Plants semidormant; maintenance growth; root shedding continues; protein levels drop; carbohydrate levels remain high.	Short days; cold air temperatures; heavy rains; soil nutrients less available to plants; soil temperatures cool; flooding possible on low-lying fields.	Graze only if soils aren't saturated and growth is greater than the minimum stubble height (the grass is very palatable!); start tracking T-Sum; utilize confinement area as needed.	Avoid grazing or equipment use when soils are saturated (causes soil compaction and plant damage); avoid overapplication of N, as this will interfere with carbohydrate storage and protective dormancy; excess N will also tend to leach or wash away with rain.
5	Increasing growth	Plant uses reserves to increase shoot and root growth and to recover from any heavy fall use; daily forage production increases; protein and carbohydrate levels are low.	Day length increases; air temperatures warming; soil nutrients increasingly available after T-Sum 200, but mineral deficiency symptoms may occur due to cool soils; soils warming and drying out.	Monitor T-Sum; make first application of nutrients and lime as needed; use a higher residual stubble height (4" for bunchgrasses, 3" for sod formers); check for weed problems; utilize confinement area as needed; establish new pastures if needed.	Avoid grazing or equipment use when soils are saturated (causes soil compaction and plant damage); avoid overapplication of nutrients; avoid grazing stubble below increased residual heights (4–6" for bunchgrasses, 3" for sod formers).

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## Table 1. Pasture Calendar Summary—*continued*

Period	Period name	What the grass is doing	Environmental factors	Management needed	Things to avoid
6a	Rapid growth— cool soils	Plant uses reserves as in Period 5, but at a faster rate, as root and shoot growth increases; seedhead develops in stem; protein and carbohydrate levels in forage are low; digestibility high; fiber concentration low.	Day length increases; spring equinox occurs; air temperatures increase; nights still cool; soils still cool; soil nutrients increasingly available.	Use a higher residual stubble height (4–6" for bunchgrasses, 3" for sod formers); make first application of nutrients and lime if not done during Period 5; utilize confinement area as needed; overseed confinement areas as needed; reseed scheduled pastures; control weeds as needed; establish new pastures if needed.	Avoid grazing or equipment use when soils are saturated (causes soil compaction and plant damage); avoid overapplication of nutrients; avoid grazing stubble below increased residual heights (4–6" for bunchgrasses, 3" for sod formers).
6b	Rapid growth— warm soils	Forage grows rapidly; quality can decline without harvest; seedheads emerge on most grass species; very rapid regrowth; root growth slows; carbohydrate levels begin to increase again in lower leaves and stems; digestibility high; fiber concentration low.	Day length significantly longer; air temperatures increase; nights cool, but no frost; soils warm; soil nutrients more available, but may not keep up with plant needs.	Use a higher residual stubble height (4–6" for bunchgrasses, 3" for sod formers); make first and second applications of nutrients and lime; reseed scheduled pastures; overseed confinement areas as needed; control weeds as needed; establish new pastures if needed.	Avoid grazing or equipment use when soils are saturated (causes soil compaction and plant damage); avoid grazing stubble below increased residual heights (4–6" for bunchgrasses, 3" for sod formers).

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## Table 1. Pasture Calendar Summary—*continued*

Period	Period name	What the grass is doing	Environmental factors	Management needed	Things to avoid
7	Slowing growth	Forage growth slows and comes mostly from vegetative tillers; plants less digestible than in Period 6, but still high quality; seedheads emerge on late species such as timothy; regrowth time increases; root growth slows; carbohydrate levels begin to decline.	Longest days of the year; summer solstice occurs; moisture adequate, but less soil moisture available; daytime and nighttime air temperatures warming; soil temperatures warming; soil nutrients very available.	Use a higher residual stubble height (4–6" for bunchgrasses, 3" for sod formers); control weeds as needed; monitor for irrigation needs; make second and third application of nutrients; cut hay before mature seed-setting phase.	Do not graze stubble below increased residual heights (4–6" for bunchgrasses, 3" for sod formers) because slowing growth rates aren't being monitored.
8	Steady growth	Less forage growth; root shedding begins; protein levels adequate; carbohydrate levels decline further; digestibility lower; fiber higher; lack of moisture (and/or high temperatures) slows growth; may start dormancy.	Daytime and nighttime air temperatures warm; soil temperatures warm; little rainfall; evaporation increases.	Minimum stubble height is critical (3" for bunchgrasses, 2" for sod formers); utilize confinement area as needed if stubble height can't be maintained; cut hay before mature seed-setting phase.	Do not graze stubble below residual heights (3" for bunchgrasses, 2" for sod formers) because slowing growth rates aren't being monitored.
9	Slow growth	Rapid root shedding; forage growth slows; drought/heat may result in very little growth or start of dormancy; protein levels adequate; carbohydrate levels still low; digestibility starts to improve.	Air temperatures usually higher than optimum for forage growth; little rainfall; soil temperatures warm; day length decreases.	Minimum stubble height is critical (3" for bunchgrasses, 2" for sod formers); utilize confinement area as needed if stubble height can't be maintained; cut hay before mature seed-setting phase.	Do not graze stubble below residual heights (3" for bunchgrasses, 2" for sod formers).
10	Dormancy	Dormancy without soil moisture or irrigation; protein levels adequate; carbohydrate levels still low because no growth is occurring.	Day length continues to decrease; air temperatures peak; little or no rainfall; soil temperatures peak.	Minimum stubble height and stubble management is critical (3" for bunchgrasses, 2" for sod formers); utilize confinement area as needed if stubble height can't be maintained; use of warm-season annuals (where adapted) can provide high nutrition.	Do not graze stubble below residual heights (3" for bunchgrasses, 2" for sod formers).

# Pasture Calendar Notes

## Period 1: Semidormancy

### Overview

**Period 1** represents the beginning of the forage calendar because it is the most critical period of the forage year. Management decisions made during **Period 1** will affect the plants' ability to overwinter, the timing of new growth initiation in the spring, and total forage produced over the entire year. Storage of carbohydrates in **Period 1** is essential for winter survival and long-term pasture health. Overgrazing or excessive forage harvesting during **Period 1** inhibits shoot formation and root system rebuilding. **Periods 1 and 2** are the most critical periods for root growth in western Oregon and Washington.

### Environmental factors/conditions

- Rain showers begin, and relative humidity increases.
- Temperatures become cooler.
- Days become shorter as the fall equinox approaches.
- Soils remain warm from summer heat.
- The release of N from the soil (soil mineralization) begins when moisture is available.
- Weeds germinate on bare patches of soil. Invasive weeds include chickweed, mallow, henbit, common groundsel, annual bluegrass, tansy ragwort, St. John's wort, thistles, and rat-tail fescue.

### What the plant is doing

- Growing points develop to provide next year's tillers (Figure 6). This is the induction phase of grass growth, according to Gardner and Loomis (1953).
- Plant root systems rebuild. Dig out a few plants with a shovel, wash off the soil and look for new, white roots developing at the crown. New roots will vary in length.
- Plant top growth begins; it always follows root development during this period.



Figure 6. Although little aboveground growth occurs during Period 1, plants are rebuilding root systems and developing growing points for next year's tillers. Photo by Marty Chaney. Used by permission of Fred Colvin.

- Seedling legumes develop a root crown (contractile root growth), the structure needed for winter survival. Established legumes store starches in the roots and crown for overwintering.
- Carbohydrate food reserves are stored in grass stubble (lower stems and crowns) and roots.
- Plants may show symptoms of rust or other diseases due to summer spore infection.

### Management needed

- Between August 15 and October 15, soil test for P, K, pH, SMP (buffer pH), and residual nitrate ( $\text{NO}_3$ ) in the top foot of soil. For interpretation of nitrate test results, see EM 8832-E, *Post-Harvest Soil Nitrate Testing for Manured Cropping Systems West of the Cascades*.
- Manure applications can be made based on soil test results and recommendations in PNW 533, *Fertilizing with Manure*.
- Provide needed fertility, paying particular attention to the soil P levels necessary for grass root regrowth and legume growth.
- Apply irrigation water if available (see Appendix 5, page 40).



- Apply agricultural or dolomitic limestone if needed, based on soil test results.
- Graze livestock only if sufficient forage is available. Do not graze below the minimum stubble heights recommended in Table 2.
- Plant fall-established pastures as recommended in EB 1870, *Pasture and Hayland Renovation for Western Washington and Oregon*.

**Table 2. Minimum residual stubble heights in Period 1.**

Growth form	Minimum residual stubble height (inches)	Typical species
Bunchgrass	3	Orchardgrass, perennial ryegrass
Sod formers	2	Bentgrass, bluegrass

Source: Fransen, 2000.

### Things to avoid

- Avoid grazing below recommended residual heights.
- Do not overfertilize with N.
- In general, keep manure applications 100 feet from open water and property lines. NRCS Technical Guides provide more site-specific information.

### Other considerations

- Clean out remaining manure from barns and lagoons. Application of manure to fields should be based on plant nutrient needs and fall soil nitrate test results. Do not cover more than 25 percent of the plant's surface area with manure (about 10 cu yd/a). Keep manure application away from open water, wells, and property lines (PNW 533, *Fertilizing with Manure*). Contact your local Natural Resources Conservation Service or Soil and Water Conservation District office for more site-specific information.
- Begin using a livestock wintering or sacrifice area when pasture forage reaches minimum stubble heights (see Appendix 3, page 38).

## Period 2a and 2b: Steady regrowth

### Overview

**Period 2** is divided into subsections, based on how much the grass has recovered from **Period 1**.

During **Period 2a**, pastures still contain considerable brown aboveground forage (Figure 7). Green tillers are evident as plants come out of semidormancy, but conditions are not fully adequate for rapid above-ground regrowth. Regrowth is slow as tillers progress through a “lag phase” of plant development, a period of slow growth due to insufficient leaf area for photosynthesis. This phase occurs just prior to early vegetative growth (Figure 15, page 35).

Make sure grasses have at least the minimum residual stubble height for nutrient storage and earlier spring growth.

During **Period 2b**, regrowth is more rapid, into the lag phase of perennial plant growth (Figure 8). Persistence of growth during this time depends on grazing, soil N mineralization, soil fertility, and weather conditions.

### Environmental factors/conditions

#### Period 2a

- Air temperatures are cooling and are ideal for cool-season grass growth.
- Soil temperatures are cooling and become more suitable for grass growth.
- Rain is more frequent and regular, which initiates regrowth.
- Soil mineralization increases if moisture is available.

#### Period 2b

- Soil mineralization progresses at a rapid rate.
- Steady rainfall may start to move nitrates below the root zone.
- Soil temperature decreases with cold rain.

### What the plant is doing

- Growing points continue development, providing next spring's tiller growth. This is the induction phase of grass growth, according to Gardner and Loomis (1953).



Figure 7. In Period 2a, plants begin to come out of semidormancy, but growth is still slow. Photo by Scott Robbins.



Figure 8. During Period 2b, weather conditions become more favorable for soil N mineralization and rapid grass growth. Photo by Scott Robbins.

- The root system continues rebuilding.
- Seedling legumes develop a root crown through contractile root growth.
- Carbohydrate food reserves are being stored.
- Potential crude protein and energy is highest at this time. Fall forage yield is lower than spring production (Figure 16, page 35). See Appendix 6 (page 41) for management to avoid laminitis.
- Cooler temperatures are favorable for early and steady grass top regrowth.

- Grass plants may show symptoms of rust and diseases due to summer spore infection.
- Plants respond to the change in environmental conditions during **Period 2** by preparing their cells for accumulation of the organic substrate proline, which serves as “antifreeze” during the winter.

### Management needed

- Final grass silage harvest of the season.
- Between August 15 and October 15, soil test for P, K, pH, SMP (buffer pH), and residual nitrate (NO<sub>3</sub>) in the top foot of soil. For interpretation of nitrate test results, see EM 8832-E, *Post-Harvest Soil Nitrate Testing for Manured Cropping Systems West of the Cascades*.
- Manure applications can be made based on soil test results and recommendations in PNW 533, *Fertilizing with Manure*.
- Provide needed fertility, paying particular attention to the soil P levels necessary for grass root regrowth and legume growth.
- Apply agricultural or dolomitic limestone if needed, based on soil test results.
- Graze livestock only if sufficient forage is available and not below the minimum stubble heights recommended in Table 3.
- See Appendix 3 (page 38) for information on confinement areas.

### Things to avoid

- Avoid commercial N fertilizer and manure applications in excess of plant nutrient needs, as vigorously growing plants are more susceptible to winter damage. Excessive N application in **Periods 1 or 2** will

inhibit the plant from starting its overwintering response, as proline will accumulate only in the absence of excessive N. In addition, as root activity declines, plants don’t take up all of the nutrients available in the soil, and unused nutrients are vulnerable to leaching.

- Avoid soil compaction from equipment or livestock traffic on saturated soils.
- Minimum stubble heights are recommended for protection of the pasture plants and soils, thus encouraging rapid regrowth, initiation of new tillers and roots, higher quality and productivity, and long-term sustainability.

### Other considerations

- Clean out remaining manure from barns and lagoons. Application of manure to fields should be based on plant nutrient needs and fall soil nitrate test results. Do not cover more than 25 percent of the plant surface with manure (about 10 cu yd/a). Keep manure application away from open water, wells, and property lines. Contact your local Natural Resources Conservation Service or Soil and Water Conservation District office for more site-specific information.
- Begin using livestock wintering or sacrifice areas when forage reaches minimum stubble heights (see Appendix 3, page 38).

**Table 3. Minimum residual stubble heights in Period 2.**

Growth form	Minimum residual stubble height	
	(inches)	Typical species
Bunchgrass	3	Orchardgrass, perennial ryegrass
Sod formers	2	Bentgrass, bluegrass

Source: Fransen, 2000; Pirelli and Fransen, 2016.

## Period 3: Declining regrowth

### Overview

The transition to fall occurs during **Period 3**, and plant growth declines (Figure 9). This is the beginning of the prolonged rest period for pastures and hayfields in western Oregon and Washington. Overuse of pastures during **Period 3** will reverse plant vigor and health gained during **Periods 1 and 2**.

### Environmental factors/conditions

- Short days make less light available for photosynthesis and cause plants to prepare for the winter slow growth period.
- Heavy rains will cause saturated soils. Saturation weakens soil structure, allows hoof and wheel traffic to damage plants, and increases the risk of soil compaction. Water fills the soil pore spaces, so no air is available for plant roots. Compacted and saturated soils also stay colder due to less air space.
- **Period 3** usually is the highest precipitation period. Flooding season begins.
- It may rain every day during **Period 3**, but high-pressure weather systems can also dominate for a week or longer.
- Nutrients are less available to plants because of denitrification, reduced nutrient uptake by semidormant plants, and leaching.
- Warm southwest winds colliding with cold north winds can cause snow accumulation, which may protect plants from winterkill.

### What the plant is doing

- Significant root rebuilding is finished, and root shedding begins.
- Plants continue to respire. Leaves may turn light yellow or tan as a result of freezing temperatures, snow cover, or prolonged rain events. Plants photosynthesize at very low rates, and very little growth occurs.



Figure 9. Short days, cool temperatures, and heavy rains lead to declining growth during Period 3. Photo by Marty Chaney. Used by permission of Fred Colvin.

- During periods of prolonged saturated soils, hydrogen sulfide gas can be produced, which increases stress on sensitive plants, especially legumes.
- Pasture plants accumulate sugars in **Period 3**, partially for protection from winter injury and partially to continue feeding apical meristems during the winter dormancy period.
- Carbohydrate levels remain high.

### Management needed

- Graze livestock only if soils are not wet or saturated and forage height is two times greater than the recommended residual stubble height (Table 4). This practice will reduce the tendency of animals to graze the high-carbohydrate stubble.
- **Period 3** is the last chance to apply lime during the current season. Apply before soils are saturated.

**Table 4. Minimum residual stubble heights in Period 3.**

Growth form	Minimum residual stubble height (inches)	Typical species
Bunchgrass	3	Orchardgrass, perennial ryegrass
Sod formers	2	Bentgrass, bluegrass

Source: Fransen, 2000; Pirelli and Fransen, 2016.

## Things to avoid

- To prevent pugging (holes made in the soil surface by livestock hooves) and compaction, avoid grazing when soils are wet or saturated. Compaction leads to lower yields due to less air space in the soil (EB 1895, *Soil Management for Small Farms*).
  - Avoid equipment use on wet pastures and saturated soils.
  - Avoid fertilizer and manure applications. Growing plants are more susceptible to winter damage. Also, because root system activity is decreased, plants take up less nutrients. Unused nutrients are vulnerable to leaching.
- Avoid grazing below recommended residual stubble heights (Table 4, page 19).

## Other considerations

- Make maximum use of your wintering or sacrifice area. Keep animals in this area unless conditions allow for limited grazing. Confinement of livestock in nonpasture areas for long time periods may require state permits. Check with your state regulatory agency for current rules. See Appendix 3 (page 38).
- Rest the pasture. This is a good time to give pastures a break and prevent damage to crowns and root systems.

## Period 4: Very slow growth

### Overview

Winter rest for pastures and hayfields should continue. Avoiding grazing during **Period 4** will enhance the ability of perennial forage plants to rebound when spring temperatures increase.

Plant crowns are susceptible to hoof damage during this time even when soils do not have standing water. Perennial plant growth often appears ragged in the early part of this period. The reason is that soil temperatures are fluctuating, and much of the new plant growth is occurring below ground.

Monitoring soil temperatures is essential for predicting when significant forage growth will begin, when adequate forage will be available for grazing, and the best time to apply N fertilizer. Sustained soil temperatures of 42°F or above at the 4-inch depth indicate that **Period 4** is ending.

T-Sum 200 summarizes heat units to calculate the best time to apply N fertilizer to stimulate early pasture growth (EM 8852, *Spring Forage Production for Western Oregon Pastures*). In the Willamette Valley and the Puget Trough, T-Sum 200 typically is reached between January 28 and February 14. In coastal valleys, T-Sum 200 is reached from approximately January 15 to January 31. In southern Oregon, T-Sum 200 ranges from January 15 to January 31.

### Environmental factors/conditions

- Periods of sustained freezing temperatures and snow can occur. Soil temperatures are cool.
- It may rain every day during **Period 4**, but a high-pressure weather system can produce clear weather for a week to 10 days.
- Heavy rains may cause saturated soils (Figure 10). Saturation weakens the soil structure, thereby allowing hoof and wheel traffic to damage plants and soils.
- Flooding continues to be a possibility throughout this period.
- Nutrients are less available to plants because of denitrification, reduced nutrient uptake by semidormant plants, and leaching.

### What the plant is doing

- Root shedding continues.



Figure 10. Saturated soils and flooding are possible during Period 4. Livestock should not be on pastures under these conditions. Photo by Marty Chaney. Used by permission of Fred Colvin.

- Plants continue to respire. Leaves may turn light yellow or tan as a result of freezing temperatures, snow cover, or prolonged rain events. Plants photosynthesize at very low rates, and very little growth occurs.
- During periods of prolonged saturated soils, hydrogen sulfide gas can be produced, which increases stress on sensitive plants, especially legumes.
- During this period, pasture plants appear to reduce translocation of N from roots to aboveground forage. Both CP and forage nitrates are at about their lowest concentration over the growing season. Sugar levels often are highest in the aboveground forage during **Period 3** compared to other periods in the Calendar because the energy is necessary for plant survival and regrowth in the spring.

### Management needed

- Graze livestock only if soils are not saturated and forage height is two times greater than recommended minimum residual stubble heights (Table 5, page 22).
- It is possible to apply small amounts of manure in January if dry conditions persist for extended periods.
- Start to track heat unit accumulations for initial N application. The T-Sum count starts on January 1.

- If needed, make the first N application at the T-sum 200 date, and apply P and S if not applied the previous fall. Nitrogen applications should be limited to those pastures that have well-drained soils and start growing first in the spring (EM 8852, *Spring Forage Production for Western Oregon Pastures*).
- Evaluate fence layout, water trough location, and grazing system design.
- See Appendix 3 (page 38) for information on confinement areas.

### Things to avoid

- To prevent pugging (holes in the soil surface by livestock hooves) and compaction, avoid grazing when soils are wet or saturated. Compaction leads to lower yields due to less air space in the soil (EB 1895, *Soil Management for Small Farms*).
- Avoid equipment use on wet pastures and saturated soils.
- Avoid fertilizer and manure applications on saturated soil. Growing plants are more susceptible to winter damage. Also, root system activity is decreased, so plants won't take up all

**Table 5. Minimum residual stubble heights in Period 4.**

Growth form	Minimum residual stubble height (inches)	Typical species
Bunchgrass	3	Orchardgrass, perennial ryegrass
Sod formers	2	Bentgrass, bluegrass

Source: Fransen, 2000; Pirelli and Fransen, 2016.

of the nutrients. Unused nutrients are vulnerable to leaching.

- Avoid grazing below recommended minimum residual stubble heights.

### Other considerations

- Make maximum use of your wintering or sacrifice area during **Period 4**. Keep animals in this area unless conditions allow for limited grazing. Confinement of livestock in non-pasture areas for long time periods may require state permits. Check with your state regulatory agency for current rules. See Appendix 3 (page 38).
- Rest the pasture. This is a good time to give pastures a break and prevent damage to crowns and root systems.

## Period 5: Increasing growth

### Overview

This is the end of the winter slow growth period. Typically, T-Sum 200 is reached in the Willamette Valley and the Puget Trough between January 28 and February 14; in coastal valleys from approximately January 15 to January 31; and in southern Oregon from January 15 to January 31. In Washington, areas farther away from the Puget Sound range from February 14 to February 28. Sustained soil temperatures of 42°F or above at the 4-inch depth indicate that **Period 5** has begun. Dig plants with a shovel, wash the root system, and look for new, white roots. Density of white roots will depend on local growing conditions.

### Environmental factors/conditions

- Late snows can occur and can be very wet. Because plants are still growing slowly, winter injury is less likely.
- Mineralization will begin at about T-Sum 200.
- Moisture is adequate, and in some cases excessive, for plant growth.
- Air temperatures are still cold but are warming as day length increases, leading to top leaf growth.
- Days of sustained freezing temperatures can occur.
- Rains start to be less frequent than in **Period 4**. Rapidly moving low-pressure weather systems may produce every-other-day rain events.

### What the plant is doing

- Root systems and rhizomes regenerate, and new tillers develop. Well-drained soils permit grass root regeneration sooner because they warm more quickly than clayey or compacted soils.
- Older roots are a major supplier of nutrients, as new roots are just starting to grow. Plants whose roots have been damaged by poor grazing management will have delayed growth.
- Leaf area accumulation is essential for plants to recover from the winter. Also, extra leaf area is necessary during this period for

photosynthesis on cloudy days. Total seasonal production will be reduced in plants that can't efficiently photosynthesize during this period.

- Nutrient uptake increases slowly. Deficiency symptoms are often evident for N, P, K, S, and Mg during this time (see Appendix 9, page 45). Minerals are mobilized from older tissue to feed developing tillers—another reason why extra leaf area is important. The aboveground portion of plants may show P deficiency, largely based on low availability of P in cold soils. As soils warm, P will become more available, and deficiency symptoms may disappear. If P deficiency symptoms continue, soils likely are P-deficient.
- After root regeneration has initiated, the root and crown supply energy for top growth.
- Daily dry matter production increases compared to **Periods 3 and 4**.
- Plants switch from mostly respiration metabolism to increasing photosynthesis.

### Management needed

- Nutrients must be available to regenerate roots, increase carbohydrate levels in the crown, and foster spring flush growth. If needed, make the first N application at the T-sum 200 date and apply P and S if not applied the previous fall. Nitrogen applications should be limited to those pastures that have well-drained soils and start growing first in the spring. If the goal is early forage production, commercial N fertilizers will provide the quickest growth response.
- On wetter fields, fertilizer, manure, or compost can be applied as soon as soils are sufficiently drained.
- Delay applying K as long as possible or after grass tetany season (**Period 6a and 6b**). This delay permits the plants to take up more Mg ions to reduce the risk of animal death from grass tetany (Mayland et al., 1990).



- Graze lightly during **Period 5** if aboveground forage height is less than three times recommended stubble heights (Table 6). Limiting grazing is critical for proper root growth and subsequent new tiller growth. Overgrazing during this period is devastating to future forage growth, as food reserves (carbohydrates) stored in the stubble can be grazed off instead of being available for plant growth.
- The first and/or second grazing should be a rapid-rotation grazing. Avoid grazing too low, too hard, or too long. Leaving more stubble height reduces pressure on the plants and will enhance future growth by permitting regeneration of the roots. Less root mass equals less overall production. Residual heights for this rapid-rotation grazing are 6 inches for tall fescue, prairie grass, annual ryegrass, and orchardgrass; 4 inches for perennial ryegrass; and 3 inches for bentgrass.
- Check pastures for weed invasion and develop a weed control program.
- Evaluate fence layout, water trough location, and grazing system design.
- Apply lime to soils that are not saturated, if needed and not applied the previous fall (EC 1478, *Soil Test Interpretation Guide*).
- Manure applications can be made based on recommendations (PNW 533, *Fertilizing with Manure*).

### Things to avoid

- Avoid grazing livestock when the soil's surface is wet or slippery. Grazing at this time causes a slick appearance, which inhibits water infiltration, the first step to soil compaction.
- Avoid fertilizing wet or saturated soils due to the risk of damage by

equipment and loss of nutrients through surface runoff.

- Avoid excessive applications of nutrients.
- Avoid grazing pastures seeded the previous fall.
- Avoid the temptation to feed only pasture. Supplement pasture with hay or other forages to maintain the proper stubble height.
- Avoid grazing below minimum residual stubble heights.

### Other considerations

- Apply nutrients at recommended rates. Manure may be applied based on a manure test; N in manure will supply some or all of the N needed by the pasture (see PNW 533). The type of livestock manure can make a significant difference in the short-term availability of nutrients.
- Make maximum use of your sacrifice area. Keep animals in this area unless conditions allow for limited grazing. Confinement of livestock in nonpasture areas for long time periods may require state permits. Check with your local regulatory agency for current rules. See Appendix 3 (page 38).
- Overseed sacrifice areas with annual ryegrass or other forage prior to moving livestock out. The hoof action of the animals will help provide seed-soil contact. The annual ryegrass will provide forage for later use and keep weeds out of the sacrifice area.

**Table 6. Minimum residual stubble heights in Period 5.**

Growth form	Minimum residual stubble height (inches)	Typical species
Bunchgrass	3	Orchardgrass, perennial ryegrass
Sod formers	2	Bentgrass, bluegrass

Source: Fransen, 2000; Pirelli and Fransen, 2016.

## Period 6a and 6b: Rapid growth

### Overview

For cool-season perennial forage plants, **Period 6** is the transition from late-winter dormancy into rapid spring growth. The spring flush of root and top growth occurs. Rapid growth during **Period 6** is an expression of proper management during **Periods 1 and 2**. What happens during **Period 6** is important for both quantity and duration of growth through **Period 10**. Because conditions change rapidly during **Period 6**, this period has been divided into segments. The segments are based on changes in soil temperature, which greatly influence the availability of soil nutrients and forage growth rate.

### Environmental factors/conditions

#### Period 6a

- Day length increases, and the spring equinox occurs during this time.
- Daytime air temperatures increase, although nighttime temperatures are still cool.
- Declining rainfall provides adequate to excessive moisture for plant growth.
- Soil temperatures are still cool.
- Soil nutrient mineralization occurs.

#### Period 6b

- Day length continues to increase.
- Daytime and nighttime air temperatures increase.
- Shorter, frequent rain showers provide adequate moisture for plant growth.
- Soils are warming.
- Soil nutrient mineralization accelerates.

### What the plant is doing

- Root systems and rhizomes regenerate, and new tillers develop. Grasses go through the initiation phase of growth and development, as shown in Figure 15, page 35 (Gardner and Loomis, 1953). The plant transitions from a vegetative to a reproductive phase.
- Maintaining leaf area is critical for proper root growth and subsequent feeding of new tiller growth. Overgrazing during this period is



Figure 11. During Period 6, new tillers develop, the seedhead stem elongates, and a seedhead is produced. Photo by Scott Robbins.

- devastating to future forage growth and plant survival.
- Nutrient uptake (Ca, Mg) increases. Tillers mobilize P from older to newer tissue.
- During **Period 6a**, plant crowns visibly thicken with new tillers. During **Period 6b**, the seedhead stem thickens and elongates. Cool-season species go to joint and produce a seedhead during **Period 6b** (Figure 11).
- During **Period 6b**, fields that are not harvested will lose some leaf area because of shading. Depending on the species, each tiller can support only three to five leaves at a time during **Period 6**. As the next leaf grows on the top, the oldest leaf on the bottom dries up and falls off. At the same time, the growing tall tillers shade out the new green tillers at the base, which are the next crop. Tall tillers also shade out legumes in the understory.
- As stems mature, the presence of larger, lower quality stems leads to increasing per-plant or per-acre dry matter weight.
- Pasture grasses are in a phase of rapid change, which is reflected in cell wall chemistry changes. **Period 6** usually lasts longer than any other pasture plant growth period. Changes to plants are fairly steady early in **Period 6 (6a)** and increase as spring temperature increase (**6b**).

## Management needed

- Closely monitor initial forage and stubble heights.
- Start monitoring soil moisture on irrigated pastures to maintain growth and stimulate regrowth (see Appendix 5, page 40).
- Keep pastures in vegetative or phase 2 of plant growth (see Appendix 1, page 33).
- Aboveground forage height should reach twice that of recommended residual stubble heights before livestock are allowed to graze (Table 7). For example, orchardgrass should be 8 inches tall before grazing.
- Minimize damage to wet soils when allowing grazing during **Period 6a and 6b**. Options include:
  - Sacrificing one pasture by allowing overgrazing during **Period 6a**, thus allowing the remaining pastures to grow and the soils to firm up.
  - Selecting early-, mid-, and late-maturing species for different pastures.
  - Using lighter grazing animals, such as sheep and goats. Because these animals cause less damage on saturated soils than cattle, they can start to graze earlier than heavier-bodied animals.
- During **Period 6b**, strategies to deal with excessive forage include:
  - Grazing the field once in the early spring, then removing it from the grazing rotation and cutting hay before returning it to the rotation.
  - Increasing livestock numbers as the growth rate increases.
  - Increasing target stubble heights and rotating more quickly.
- Apply nutrients at recommended rates. Manure may be applied based on a manure test, with the N in the manure

supplying some or all of the N needed by the pasture (PNW 533, *Fertilizing with Manure*).

- Clip, spray, or weed-wipe pastures as needed to control weeds. Control broad-leaved weeds when small.
- Till and seed pastures as recommended in EB 1870, *Pasture and Hayland Renovation for Western Washington and Oregon*.

## Things to avoid

- Avoid grazing livestock when the soil's surface is wet or slippery.
- To avoid damage by equipment and loss of nutrients through surface runoff, avoid fertilizing wet or saturated soils.
- Avoid excessive applications of nutrients.
- Avoid grazing pastures seeded the previous fall.
- Avoid the temptation to feed only pasture. Also feed hay or other forages to maintain the proper stubble height.
- Avoid grazing below minimum residual stubble heights.

## Other considerations

- Overseed sacrifice areas with annual ryegrass or other forage prior to moving livestock out (EB 1870). The hoof action of the animals will provide seed-soil contact. The annual ryegrass will provide forage for later use and keep weeds out of the sacrifice area. See Appendix 3 (page 38).

**Table 7. Target start-up heights and residual stubble heights for grasses during Period 6a and 6b.**

Grass species	Minimum grazing start-up height (inches)	Minimum residual stubble height (inches)
Orchardgrass	8	4
Tall fescue	8	4
Perennial ryegrass	6	3
Bentgrass	4	2

Source: Fransen, 2000; Pirelli and Fransen, 2016.

## Period 7: Slowing growth

### Overview

Growth during **Period 7** is slower than during **Period 6**. Growth continues during this time, but average daily dry matter accumulation is reduced. For most adapted cool-season grasses, nearly all of the seedheads have elevated and are visible. Fewer than 10 percent of the remaining tillers will develop seedheads during the remaining portion of the growing season. Regrowth from now until the next **Period 6** will depend on the vegetative tillers that do not produce seedheads at this time.

### Environmental factors/conditions

- Longest days of the year and summer solstice occur.
- Adequate soil moisture is still present, but rainfall is declining.
- Daytime air temperatures increase. Nighttime temperatures are still cool, but beginning to warm.
- Soil temperatures are warming.
- Soil N mineralization increases rapidly, making additional N available to plants.

### What the plant is doing

- Plants will produce a seedhead if they did not do so during **Period 6b**. If the seedhead was harvested earlier in the season (**Period 6a**), regrowth during **Period 7** will be vegetative. If the seedhead was not removed, such as with grazing animals in either **Periods 5 or 6**, then a flush of seedheads will appear in **Period 7**. Reproductive tillers have completed the jointing and boot stage of plant growth, so the inflorescence will be in full view (Gardner and Loomis, 1953).
- Growth slows.
- Plants become less digestible but are still high quality.
- Plants will not recover as quickly from overgrazing, so maintaining proper stubble height is important to reduce weed seedling pressure during **Periods 1 and 2**.
- Carbohydrates are stored in the stubble during this period.

### Management needed

- Maintain pastures in vegetative or phase 2 growth stage.
- Target start-up and residual heights are the same as in **Period 6** (Table 7, page 26).
- Make sure hay fields are cut before phase 3 (mature seed-setting phase) or boot stage to keep them vegetative and available for grazing when they regrow above the minimum stubble height.
- If grazing after hay removal, do not begin to graze until adequate forage is available above the minimum stubble height and then graze down just to the minimum stubble height.
- Clip, spray, or wipe pastures as needed to control weeds, as recommended in the *PNW Weed Management Handbook*.
- Monitor soil moisture for irrigated pastures (see Appendix 5, page 40).
- As the growth rate slows, more acres per animal are needed. Rotate animals to harvested hay fields where adequate growth has been achieved or to areas that are used strictly as summer pasture, such as wet bottomlands.
- Apply N at a rate and timing based on intended use (hay or pasture), species of plants, and anticipated hay yield or stocking rate. Manure may be applied based on a manure test, with the N in the manure supplying some or all of the N needed by the pasture (PNW 533, *Fertilizing with Manure*).

### Things to avoid

- Avoid the temptation to graze pastures below the minimum stubble height. Adjust stocking rates or feed hay to maintain stubble height.
- Avoid letting hay reach phase 3 (mature seed-setting phase) before cutting.
- Avoid overgrazing. As plant growth rates decrease, pay close attention to plant heights and the speed of rotation through pastures.
- Avoid damage to wet fields by hay machinery.

## Period 8: Steady growth

### Overview

Warmer nighttime temperatures increase soil temperature, so the growth of some plants, such as clover and some weeds, increases. Evaporation also increases, causing what little rainfall that does occur to be less effective. Water becomes limited in the soil profile unless irrigation is available. Plants may be under water stress during the heat of the day, resulting in steady but slower daily growth rates than in **Period 7**.

### Environmental factors/conditions

- Daytime air temperatures climb, and nighttime temperatures stay warmer.
- Rainfall declines rapidly.
- Soil temperatures increase, further drying the soil.
- Animal needs may exceed forage production.

### What the plant is doing

- The inflorescence is fully mature.
- Plants begin to shed roots, as indicated by a change in root color from white to tan to brown and possibly black. Dig a few plants and wash the roots to see this response.
- Plant growth occurs if adequate moisture is available.
- Plants may start into summer dormancy because of lack of available soil moisture.
- Carbohydrates are being stored in the stubble.

### Management needed

- Keep stocking rates in balance with grass growth. You may need to move some animals to corrals, increase acres, or provide supplemental feed.
- Fine-grained soils usually provide growth later into the summer. They can be fenced separately and grazed when adequate forage is available above minimum stubble heights.

- Use irrigated pastures or irrigated annual forages during this period.
- Make sure hay fields are cut before phase 3 (mature seed-setting phase) to keep them vegetative and available for grazing if they regrow above the minimum stubble height.
- When grazing after hay removal, do not begin until adequate forage is available above the minimum stubble height (Table 8), and then graze down just to the minimum stubble height.
- Clean out barns and lots and apply manure at agronomic rates to fields that have been grazed to minimum stubble heights. Manure applications can be calculated using PNW 533, *Fertilizing with Manure*.
- To reduce rust infection in **Period 1**, apply N in **Periods 8 and 9** to susceptible species and varieties.

### Things to avoid

- Avoid the temptation to graze pastures below the minimum stubble heights. Adjust stocking rates or feed hay to maintain stubble height.
- Avoid letting hay reach phase 3 (mature seed-setting phase) before cutting.

### Other considerations

- Continue monitoring soil moisture for irrigation needs (see Appendix 5, page 40).

**Table 8. Target start-up heights and residual stubble heights for grasses during Period 8.**

Grass species	Minimum grazing start-up height (inches)	Minimum residual stubble height (inches)
Orchardgrass	8	3
Tall fescue	8	3
Perennial ryegrass	6	2
Bentgrass	4	2

Source: Pirelli and Fransen, 2016.

## Period 9: Slow growth

### Overview

Higher temperatures and lack of soil moisture significantly slow growth of grasses. Legumes and other species that are adapted to warmer temperatures continue to grow vigorously until soil moisture becomes limiting.

### Environmental factors/conditions

- Temperatures are warmer than optimum for grass growth.
- Very little or no rainfall occurs.
- Soil temperatures increase rapidly.
- Days become shorter.

### What the plant is doing

- Plants shed older roots.
- Plant growth occurs if adequate soil moisture is available.
- Plants may start into or have already achieved summer dormancy.
- Carbohydrates are stored in the stubble.

### Management needed

- Keep stocking rates in balance with grass growth. You may need to move some animals to corrals, increase acres, or provide supplemental feed.
- Fine-grained soils usually provide growth later into the summer. They can be fenced separately from other fields and grazed when adequate forage is available above the minimum stubble heights (Table 9).
- Use irrigated pastures or irrigated annual forages during this period.
- Make sure hay fields are cut before phase 3 (mature seed-setting phase) to keep them vegetative and

available for grazing if they regrow above the minimum stubble height.

- When grazing after hay removal, do not begin until adequate forage is available above the minimum stubble height, and then graze down just to the minimum stubble height.
- Clean out barns and lots and apply manure at agronomic rates to fields that have been grazed to the minimum stubble heights. Manure applications can be calculated using PNW 533, *Fertilizing with Manure*.
- To reduce rust infection in **Period 1**, apply N to susceptible species and varieties during **Periods 8 and 9**.

### Things to avoid

- Avoid the temptation to graze pastures below the minimum stubble heights. Adjust stocking rates or feed hay to maintain proper stubble height.
- Avoid letting hay reach phase 3 (mature seed-setting phase) before cutting.

### Other considerations

- Properly composted manure may be applied based on nutrient content and soil test results.
- Continue monitoring soil moisture for irrigation needs (see Appendix 5, page 40).

**Table 9. Target start-up heights and residual stubble heights for grasses during Period 9.**

Grass species	Minimum grazing start-up height (inches)	Minimum residual stubble height (inches)
Orchardgrass	8	3
Tall fescue	8	3
Perennial ryegrass	6	2
Bentgrass	4	2

Source: Pirelli and Fransen, 2016.

## Period 10: Dormancy

### Overview

The end of the forage calendar year is a dormant time for most plants. Protecting the energy stored within the plants is important because the energy will be needed to provide rapid, vigorous resumption of growth when fall rains return.

### Environmental factors/conditions

- Days continue to become shorter.
- Daytime air temperatures are highest of the year.
- Very little or no rainfall occurs.
- Soil temperatures are the warmest of the year.

### What the plant is doing

- Plants are summer-dormant.
- Plants store sugars that will be used to initiate growth when fall rains return.
- Plant roots continue to shed.
- In some areas, plants may grow due to subsurface moisture, irrigation, or deep root systems.

### Management needed

- Once minimum residual stubble heights are reached on all pastures, other forage must be provided, such as hay or silage.
- Fine-grained soils usually provide growth later into the summer. They can be fenced separately from other fields and grazed when adequate forage is available above the minimum stubble heights.
- Use irrigated pastures or irrigated annual forages during this period.
- In warmer areas, use of warm-season annuals, such as forage chicory, Sudan grass, sorghum-Sudan mixes, and forage plantain can provide high nutrition during

this typically low nutritional period (see Appendix 10, page 47).

- Make sure hay fields are cut before phase 3 (mature seed-setting phase) to keep them vegetative and available for grazing if they regrow above the minimum stubble height (Table 10).
- When grazing after hay removal, do not begin until adequate forage is available above the minimum stubble height, and graze down just to the minimum stubble height.
- Clean out barns and lots and apply manure at agronomic rates to fields that have been recently grazed. Manure applications can be calculated using publication PNW 533, *Fertilizing with Manure*.

### Things to avoid

- Avoid the temptation to graze pastures below the minimum stubble height. Adjust stocking rates or feed hay to maintain stubble height. Overgrazing in **Period 10** will slow the transition into **Period 1**.
- Avoid letting hay reach phase 3 (mature seed-setting phase) before cutting.

### Other considerations

- Properly composted manure may be applied based on nutrient content and soil test results.
- Continue monitoring soil moisture for irrigation needs (see Appendix 5, page 40).

**Table 10. Target start-up heights and residual stubble heights for grasses during Period 10.**

Grass species	Minimum grazing start-up height (inches)	Minimum residual stubble height (inches)
Orchardgrass	8	3
Tall fescue	8	3
Perennial ryegrass	6	2
Bentgrass	4	2

Source: Pirelli and Fransen, 2016.

## Table 11. Summary of Typical Activities and Events within the Pasture Calendar

Activity or event	Period											
	1	2a	2b	3	4	5	6a	6b	7	8	9	10
<b>Alternative feeds</b>												
Alternative forage crops—fall planting	X	X										
Use alternative fall-planted forage crops							X	X	X			
Alternative forage crops—spring planting						X	X	X				
Use alternative spring-planted forage crops									X	X	X	X
Alternative forage crops—summer planting								X	X	X		
Use alternative summer-planted forage crops	X	X									X	X
<b>Fertility</b>												
Take soil samples	X	X	X				X	X				
Lime applications	X	X	X					X	X	X	X	X
Potassium and/or phosphorus fertilizer applications	X	X				X	X	X	X	X	X	
Nitrogen fertilizer applications (irrigated/nonirrigated)	X	X	*	*	*	X	X	X	X	X	X	
Manure applications	X	X				X	X	X	X	X	X	X
<b>Forage management</b>												
Maintain recommended stubble height	X	X	X	X	X	X	X	X	X	X	X	X
Hay/silage making	X	X						X	X	X	X	
Potential forage nitrate problems	X								X	X	X	X
Grass tetany season							X	X	X			
Milk fever season								X	X	X	X	
Control weeds	X	X				X	X	X	X	X	X	X
Potential grazing seasons	X	X	X			X	X	X	X	X	X	X
Potential feeding seasons for hay/silage	X	X	X	X	X	X	X	X	X	X	X	X
Establish new perennial seedings	X	X				X	X	X				
Potential use of sacrifice/confinement areas	X	X	X	X	X	X	X	X	X	X	X	X
Potential irrigation season	X	X						X	X	X	X	X

\*Not recommended.

*continues on next page*



**Table 11. Summary of Typical Activities and Events within the Pasture Calendar—continued**

Activity or event	Period											
	1	2a	2b	3	4	5	6a	6b	7	8	9	10
<b>Roots</b>												
Root regeneration	X	X	X			X	X	X				
New growing points initiated	X	X	X									
New growing points expressed							X	X	X			
Root shedding				X	X					X	X	X
<b>Top growth</b>												
Plant top growth starts	X					X	X					
Plant top growth steady		X							X			
Plant top growth slows			X	X	X					X	X	
Plant top growth rapid							X	X				
Plant dormant	X										X	X
Forage digestibility high	X	X	X	X			X	X				
Protein levels high or adequate	X	X	X								X	X
Protein levels low				X	X	X	X			X		
Carbohydrate levels high or adequate	X	X	X	X	X			X				
Carbohydrate levels low						X	X		X	X	X	X
<b>Weather</b>												
Rain showers return	X											
Rain more frequent and regular		X	X				X	X				
Heavy rains and/or saturated soils				X	X	X						
Rain showers diminishing									X	X		
Very little or no rainfall										X	X	X

## Appendix 1. How Pasture Plants Grow

Stephen K. Barnhart, Extension agronomist, Iowa State University, Ames, Iowa. Used by permission.

To make good pasture management decisions, you need to understand the growth and development of grasses and legumes. Pasture use and production can be improved by carefully managing forage plant grazing. Making grazing decisions based on plant growth may seem unappealing, but it is the key to successful grazing management.

### Structure of the grass plant

The structure of grass plants is similar among the many species of grasses (Figure 12). A grass plant is a collection of tillers or shoots that grow from buds at the base of the plant. Each tiller is composed of a series of repeating units consisting of a leaf, stem node, stem internode, and a bud. Each leaf is attached to the stem at a node, with an associated dormant bud. Early in the development of a grass tiller, the distance between nodes (internodes) on the stem is very short and the stem remains compact at the base of the plant. At the top of the stem is the growing point where new stems and leaves originate. As long as this growing point remains intact, it is capable of producing new leaves. Later in the development of the tiller, the growing point undergoes a change. It stops producing leaves and begins to form the immature seedhead of the plant. After this, the growing point on this tiller is no longer capable of producing any more new leaves, and grazing or clipping it off has no impact on further new leaf numbers. Once this transition occurs, some of the upper internodes begin to elongate and eventually raise the seedhead to the top of the tiller. New tillers emerge from the plant crown as regrowth.

### How grasses develop

Grass develops through a sequence of stages. There are three primary developmental stages in grasses that you should be able to recognize for grazing management (Figure 13):

1. Vegetative
2. Elongation
3. Reproductive

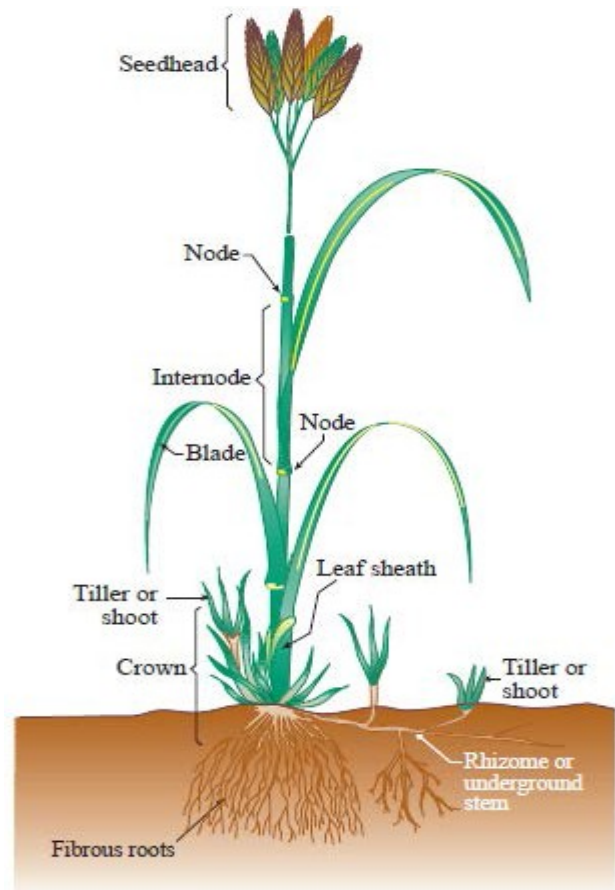


Figure 12. The parts of a grass plant. (Not all grasses have rhizomes, but all grasses do have fibrous roots.)

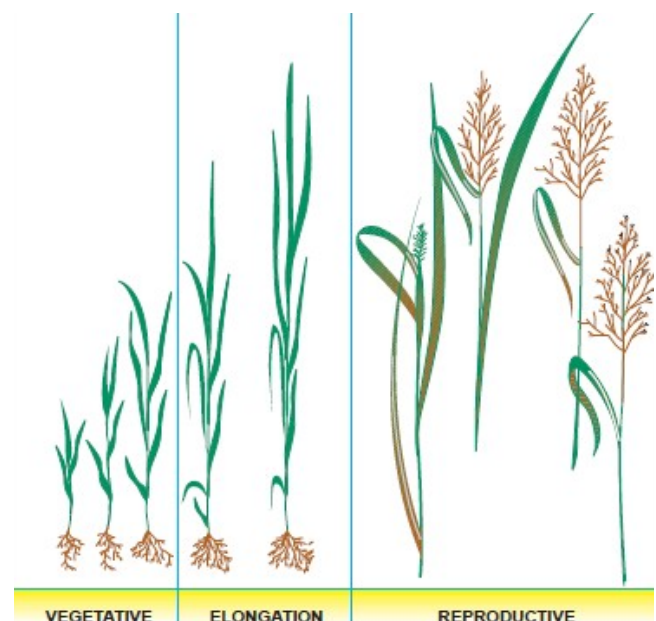


Figure 13. Developmental stages of grass growth.

The vegetative growth period is the growth of leaves. The stem, with its growing point, remains compact near the soil line. Once a critical number of leaves has formed on a tiller, the older and lowermost leaves generally die at approximately the rate of new leaf growth, and the number of leaves on a tiller remains relatively constant.

Elongation is the stage during which stem internodes lengthen. This is sometimes called jointing. The elongation stage usually begins in response to changing length of days. During this stage, only the upper internodes elongate. The lower internodes do not elongate and remain at the base of the plant. These lower nodes, internodes, and dormant buds, together with related tillers, form the crown of the plant. When the developing seedhead begins to push through the uppermost leaf sheath, the plant has reached “boot stage,” the end of elongation. The reproductive stage is the period when the seedhead develops, pollination occurs, and seed develops.

### Structure of legumes

Legumes are a special class of plants that can “fix” atmospheric N into their own plant-available N. Legume development differs from that of grasses. Stems begin to grow in length immediately with leaves arranged alternately on opposite sides of the stem (Figure 14). Legume stem length and amount of branching varies among species. Legumes can branch at leaf-stem junctions. Flowers can form on the main stem or on branches.

### How legumes develop

Legumes develop as vegetative growth to an early stage of reproduction called bud stage. Buds are green, immature flowers that develop quickly to open bloom or flowering stage. Legumes also have many potential regrowth points. In addition to the buds at the stem tip and along the stem at each leaf-stem junction, most legume species also have dormant buds at the stem base, or crown, of the plant.

These crown buds are the source of the first growth in the spring and can quickly produce new, leafy regrowth when growing stems are grazed or clipped.

An obvious difference among forage legume species is the type of growth habit. Alfalfa has an upright growth habit. Red clover and birdsfoot trefoil have an intermediate growth habit. White clover is a pasture legume that grows close to the ground. The stems of white clover (stolons) lie flat on the soil surface and spread by buds along the stem, forming stem branches.

### Plant growth, growth rate, and growth cycles

Plants “capture” solar energy with their leaves and convert it to plant-usable carbohydrates during photosynthesis. Some of the energy is converted to proteins, fiber, oils, etc., as the plant develops new leaves, stems, and seeds. Much of the energy is used in respiration during the many plant growth and development processes. Unused carbohydrates accumulate or are stored in the roots and plant crown. The balance of these energy processes determines the health and vigor of each pasture plant.

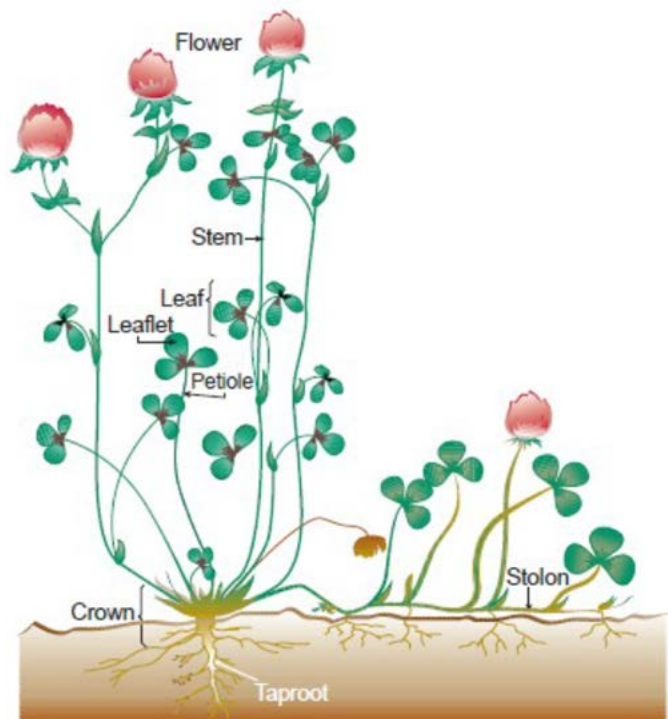


Figure 14. The parts of a legume plant. (Not all plant parts are present on all species.)

Growth rate is how fast the plant adds new dry weight over a period of time. Figure 15 shows the typical pattern of growth rate and yield. When a plant is short, with minimal leaf area, its daily growth rate is slow. As the plant accumulates increasingly more leaf area, its ability to capture sunlight increases rapidly, and its growth rate per day reaches its highest level in the late vegetative phase. As stems develop to flowering and seed production, few new leaves form and the lower, older leaves die, growth rate slows, and yield levels off. During reproduction, the dry weight of the plant is not increasing but is being redistributed within the plant as stems mature and seeds develop.

Each pasture plant begins its growth in the spring from dormant crown buds, using carbohydrates stored in the roots and crown the previous growing season. The plant's early spring growth rate, though relatively slow, is strong as long as there is an ample supply of stored energy. Spring growth can be as much as 2 weeks earlier when plants are vigorous.

When stored energy levels are low because of overgrazing the previous year, regrowth and the production of new leaves proceeds at a very slow rate. As plants grow and leaf area increases, growth rate and plant development can proceed rapidly and restore the level of stored carbohydrates.

### Seasonal growth and pasture production

Productivity of forage plants in pastures varies throughout the growing season. An important classification of pasture grasses is whether they have their highest growth rates during the cool portion of the growing season (cool-season grasses), or whether their growth rates are greatest during the warmer days of the growing season (warm-season grasses). Figure 16 shows that cool-season grasses, such as Kentucky bluegrass, orchardgrass, and brome grass, produce most of their seasonal yield in the cooler spring and autumn months, whereas warm-season grasses (switchgrass, big bluestem, sudangrass) are most productive during the warm summer months. Legumes, such as alfalfa, clovers, and birdsfoot trefoil, generally are less influenced by seasonal temperature than grasses and produce growth more uniformly throughout the growing season. Legumes, however, still grow most rapidly during the spring months.

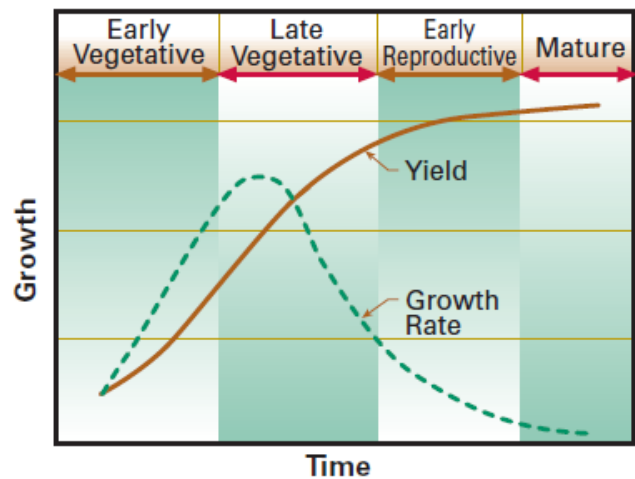


Figure 15. Growth rate changes during a growth cycle.

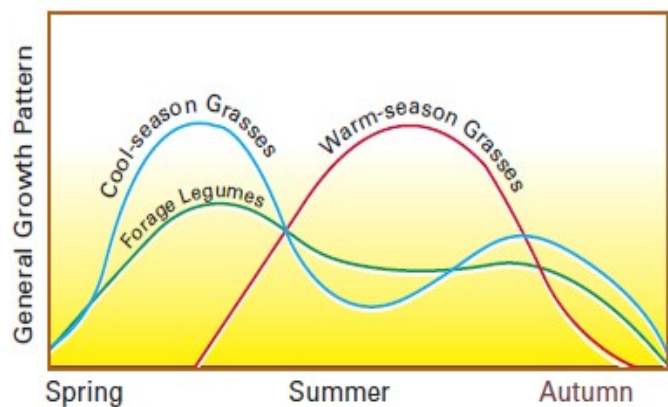


Figure 16. Different types of pasture plants are productive during different parts of the grazing season.

The growth patterns shown are the idealized pattern where nothing interferes with a plant as it grows. The productivity of the pasture at any time during the grazing season is determined primarily by the types of pasture plants, weather, and soil conditions. This productivity is also influenced by grazing management, leaf area, rest periods, and the vigor of the pasture plants.

### Grazing and growing points

In the spring, the leaves of grasses grow from an active growing point near the soil surface. Grazing will remove only leaf tips without greatly interfering with the activity of the growing point. As changes in length of days and temperature cause the elongation of the seed stem, the growing point is elevated and can be removed by grazing or harvest (Figure 17, page 36). If the active growing point is removed, leafy tiller growth develops from dormant

basal buds as new tillers. Most pasture grasses produce seedstems only in the spring. After an initial grazing or hay harvest in late spring removes the seedstems, only leafy vegetative growth is present for the remainder of the grazing season. Warm-season grasses, such as switchgrass, undergo the same basic developmental stages and recovery responses, only a month or two later, during the warmer summer months.

For legumes, the location of growing points helps determine the response to grazing. The growing point for alfalfa is near the tip of the growing stem and is easily removed by grazing. The growing points of red clover and birdsfoot trefoil are lower on the plant and less susceptible to removal by grazing. Alfalfa, red clover, and birdsfoot trefoil will quickly produce new, leafy regrowth from dormant crown buds and lower stem branches when the growing stems are grazed or cut. The growing points of white clover are at the soil surface on trailing stolons and are virtually resistant to removal by grazing, but can be damaged by hooves.

### Grazing and leaf area management

If grazing animals remove only a small amount of the active green leaf area, photosynthesis can proceed and the plant can replenish carbohydrate stores while top and root growth is progressing. But if grazing animals remove most of the available leaf area every few days, the plant allocates nearly all growth energy to new leaf growth, the root system diminishes, and less energy is stored. This frequent leaf removal without adequate time for the plant to restore its vigor is the physiological basis of overgrazing. Overgrazed pastures produce far below their potential, maintaining only a low stand density and poor vigor.

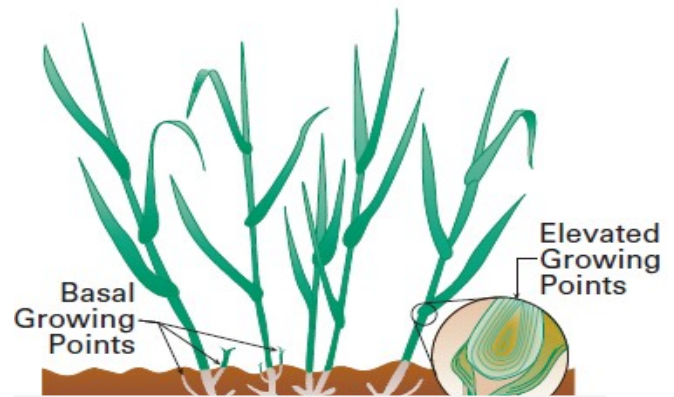


Figure 17. Elevated growing points are vulnerable to removal by grazing.

The amount of rest that a grazed plant requires to recover its vigor and replenish an effective leaf area is influenced by the period in the growing season and the amount of active leaf area remaining following the grazing period. A cool-season grass can recover in 2 to 3 weeks during its ideal spring and autumn growing periods, but may require 6 weeks or more to recover during the more stressful months of July and August. Warm-season grasses, on the other hand, grow very slowly during the cool months of spring and autumn, but recover quickly following 4 to 6 weeks of rest during their ideal summer growing period. The rest (or recovery) period can be shortened somewhat by leaving a taller leaf area remaining following grazing. This residual leaf area can contribute photosynthesis energy quickly, supplementing stored energy reserves to aid in a much faster recovery. Cool-season grasses and mixed cool-season grasses and legumes should have 3 to 4 inches of residual leaf area for rapid recovery; leave about 4 to 8 inches of leaf area on warm-season grasses following grazing

## Appendix 2. Pasture Clipping

Pasture clipping or mowing can be an important tool in the pasture manager's toolbox (Figure 18). Clipping allows the manager to precisely control pasture stubble heights before and after grazing.

Normally, grazing livestock can be expected to maintain desirable stubble heights. However, many pastures contain a mix of species and conditions, leading to uneven residual height after grazing. Clipping will help bring these pastures "back into control."

Although clipping requires an expenditure of fuel, machinery, and labor, it provides several benefits. For example, it reduces the height of "wolfy" plants—tall, ungrazed, unpalatable grasses that livestock avoid. Often, wolfy plants grow through dung piles or urine spots. If a pasture contains an abundance of these plants, other management considerations besides clipping may be needed.

Other good reasons to clip pastures are:

- *Weed control.* Weeds utilize water, nutrients, and sunlight needed by forage plants for growth and production. They also occupy space that otherwise would be occupied by forage plants. In newly seeded pastures, clip to control weed seedling development. In established pastures, clipping weeds before they

produce flowers and seed reduces the spread of weed seeds. Excessive weeds in an established pasture may be the result of improper grazing or fertility management practices and may require additional management solutions.

- *To improve palatability ahead of grazing.* Clipping before turning in livestock will increase sugar concentration and palatability in the wilted grass compared to standing grass.
- *To encourage stemmy forage plants to send up new green shoots.* If a pasture has not been grazed to recommended stubble heights, excessive residue may interfere with vegetative regrowth. Clipping will remove this residue, resulting in more desirable forage for grazing when vegetative growth occurs. It will also promote faster drying during wet winter conditions, but do not clip when soils are wet.
- *To keep livestock from grazing fall regrowth too short.* By clipping stemmy plants to 4 to 6 inches, the residual stiff stem bases will protect the new shoots from being grazed too short.

Always leave at least 3 to 4 inches of stubble after clipping.



Figure 18. Clipping pastures helps keep forage in vegetative stage and prevents weeds from going to seed. Photo by Susan Kerr.

## Appendix 3. Sacrifice Areas

A sacrifice or confinement area is an area, such as a corral, where animals can be confined and fed when pastures are too wet or too short to graze (Figure 19). When soils are saturated, animal traffic can cause compaction and rutting, reducing the soil's ability to hold moisture and air during subsequent growing seasons. In addition, plant bases will be damaged, reducing forage productivity.

A sacrifice area is often necessary in the winter, but may also be needed during the grazing season when average plant height drops to the minimum residual stubble height. When pastures are grazed too short, production is reduced, often with effects that last 1 to 2 years or even more. Use of a sacrifice area during the grazing season will protect the forage plants and soil, enabling pastures to produce to their potential throughout the season and subsequent seasons.

The best location for a sacrifice area is near a road or barn, so that livestock can be easily fed and watered. Locate the area as far as possible from wellheads and surface water, such as streams, lakes, and wetlands. The soil should be well drained, so that animals aren't standing in mud. Where mud is a problem, use materials such as hog fuel, sawdust,

bark, sand, shredded rubber, or gravel (with a geotextile fabric filter cloth underneath) to make a drier surface. If an area is extremely gravelly, use a material such as hog fuel to decrease the chance of manure leaching toward groundwater. Speak with your local Extension agent, NRCS conservationist, or Soil and Water Conservation District technician for detailed instructions.

Divert all "clean" water (such as roof water or runoff from driveways or slopes above the sacrifice area) away from the sacrifice area in order to keep the area drier and to keep clean water clean. This also reduces the chance of manure running off from the area. The local NRCS/SWCD office can assist with design of clean water diversion practices, as well as sacrifice area location and sizing.

Develop a filter/buffer strip at the downhill edge of sacrifice areas and corrals in order to capture sediment, nutrients, and pathogens from water or manure runoff. The filter strip should be at least as wide as the sacrifice area. On steeper slopes, filter strips should be wider. A well-vegetated pasture can double as a filter strip. See Appendix 4 (page 39) for more information.



Figure 19. Use of a sacrifice area prevents animals from being on a pasture that is too wet or too short to graze. Photo by Susan Kerr.

## Appendix 4. Buffer Strips for Western Oregon and Washington Farms

A buffer strip is an area of perennial vegetation that protects one type of land use from another. On livestock farms, buffer strips can be used at the downslope edges of pastures or confinement areas. A buffer of grass, shrubs, and/or trees can provide several benefits, including filtering mud, manure, nutrients, pesticides, and bacteria out of water flowing across or through the soil; providing food and cover for wildlife, including pollinators; providing flood protection; and creating an attractive landscape. Excluding animals from the buffer strip will prevent overgrazing or trampling of this protective vegetation.

While buffer strips can be installed just to buffer, many serve multiple purposes. Properly managed buffers can produce income through harvested products, while still providing many environmental benefits. For example:

- Surplus growth on shrubs can be harvested seasonally and marketed to florists for greenery or wreaths.
- Densely planted trees can be thinned for pulp or other wood products.

### Summer pasture/winter filter

A grazed pasture may also function as a buffer if it is managed for taller stubble heights and not grazed during the buffering season. This type of buffer consists of a pasture managed in a grazing rotation or cut for hay in the spring and summer. The leaves and root system then function as a buffer during times of slow growth, steady rain, or potential flooding. In western Oregon and Washington, the rainy season often extends from October through April. With this type of buffer, also develop a winter confinement or sacrifice area and use it as needed based on soil, plant, and weather conditions (see Appendix 3, page 38).

This type of buffer requires intensive management, with brief, frequent rotation of livestock through a series of pastures. As with all pasture and hayland areas, grasses should never be grazed or mowed below the proper stubble height for the species and season. The field should never have animals or equipment on it when soils are saturated.

Buffer width depends on slope, forage species, field characteristics, soil type, and plant density. If no local regulations exist for minimum buffer widths, establish at least a 30-foot buffer. Use greater widths on steeper fields, fine-grained or dense soils, or where plants are widely spaced. Distances should also be greater if the area above the buffer is not well vegetated. If a paddock is used both as summer pasture and winter filter, width often is not an issue, as almost all fields are wider than 35 feet. Livestock should be kept away from direct contact with streambanks and edges of other water bodies.

When preparing a buffer for fall and winter, it is important to remember:

- Keep grass height to a minimum of 3 to 4 inches at all times during the buffering period.
- Do not apply fertilizer or stockpiled manure in the fall, as you want this area to capture nutrients and bacteria, not release them.
- The buffering period should begin about 30 days before consistent fall rains and/or flooding is expected. This will allow time for manure deposited in the field during grazing to break down and for plants to regrow.
- The buffer period should extend into the spring until soils are firm, grasses are tall enough to graze (or otherwise harvest), and the chance of flooding has ebbed.



## Appendix 5. Irrigation for Western Oregon and Washington Pastures

Irrigating western Oregon and Washington pastures and hay fields with lagoon effluent or clean water provides additional water when soil moisture is low in the summer and early fall (**Periods 7, 8, 9, 10, and 1**). Many western Oregon and Washington soils are high in organic matter and clay content, which tend to increase water-holding capacity. On these soils, irrigation can significantly increase yields.

Keep your legal water right documents in your file and on record. Know the amount of water available to you before planning irrigation. Develop a comprehensive irrigation water management plan.

Irrigate only the number of acres for which you can supply adequate water during the entire season. It is better to adequately water a few acres than to inadequately water a larger number of acres. The goal is to maintain continued plant growth. A plant that receives some, but not enough, water will try to continue growing, rather than seeking the protection of dormancy, thereby weakening the plant. Plants use moisture for cooling as well as growth, and insufficient moisture will cause the growing plant to overheat, often leading to death. In contrast, a plant with no moisture will go dormant—a natural defense against drought—and will green up in the fall.

In dry years, irrigation may be needed as early as **Period 6b**. It's important to start irrigation on time because it takes a lot less moisture to keep a plant growing than to break drought-induced dormancy. Irrigation should begin before the soils become dry enough that they signal the plants to go into dormancy. Generally, irrigation should begin when soil moisture is about 50 percent or less.

Begin monitoring soil moisture during **Period 6b**. A good tool for estimating soil moisture is *Estimating Soil Moisture by Feel and Appearance* (USDA Program Aid Number 1619). Electronic monitoring tools are also available, including resistance blocks, tensiometers, neutron probes, frequency domain reflectometry, and time domain reflectometry sensors. Agrimet and WSU Ag Weather Net are excellent websites for more information.

Maintain soil moisture above 50 percent in the top 2 or 3 inches. With current hand sensor technology, it is challenging to maintain the 50 percent

moisture goal. However, by using irrigation scheduling techniques and close field monitoring, severe drought conditions can be prevented in most western Oregon and Washington pastures.

Determine the infiltration rate of the soils you are planning to irrigate so you do not overapply water. Make sure the quality of the irrigation water will not negatively affect pasture plants.

To prevent pugging, livestock should not be in a pasture during irrigation and until the soil surface dries, unless irrigated soils are dry enough to support the weight of the animal.

An excellent resource is Chapter 6 of *Pasture and Grazing Management in the Northwest* (Neibling et al., 2010).

### Period 7: Slowing growth

As much as 1 to 2 inches of weekly irrigation or rainfall may be needed to maintain soil moisture above 50 percent in the top 2 or 3 inches. Total forage production will be reduced if plants are water stressed, even for a short time.

### Period 8: Steady growth and Period 9: Slow growth

As much as 1 to 2 inches of weekly irrigation or rainfall may be needed to maintain soil moisture above 50 percent in the top 2 or 3 inches. Weather conditions can rapidly deplete soil moisture from now through **Period 10**.

### Period 10: Dormancy

As much as 1 to 2 inches of weekly irrigation or rainfall may be needed to maintain soil moisture above 50 percent in the top 2 or 3 inches.

### Period 1: Semidormancy

Continue to irrigate pastures until rains return and nonirrigated pastures have received rainfall. It is best to allow about 7 to 8 inches of fall regrowth before grazing nonirrigated pastures.

As much as 1 inch of weekly irrigation or rainfall may be needed to maintain soil moisture above 50 percent in the top 2 or 3 inches.

## Appendix 6. Laminitis and Pasture Management

Laminitis is an inflammation within the sensitive laminae of equine feet. A common cause is diet, specifically a diet high in starches or sugars, especially if there is an episode of rapid or large intake of starch or sugars. Grains are very high in starches. The cool-season grasses common to western Washington and Oregon can be high in sugars, especially fructans. Perennial legumes are low in fructosan sugar but high in starch.

Fructans are the primary reserve carbohydrate stored in cool-season grasses. They are concentrated primarily in the lower part of grass stems (the “stubble”) and in the seedheads. Fructan concentrations in grass stubble are especially high in the fall and early spring, when days are cool and plants are growing slowly. Although plants are not increasing in size very quickly at this time, they are still photosynthesizing and producing sugars. These unused sugars are converted to fructans and stored primarily in the stem bases.

Conditions that favor storage of fructans in cool-season grasses include those that cause grass production to slow:

- Cool nights and warm, sunny days
- Lack of fertility
- Heavy frost
- Young, vegetative (“lush”) grass leaves
- Drought stress (in autumn)

These factors are typical of early spring and autumn conditions in most areas west of the Cascades, which explains why more cases of laminitis are seen at those times.

The common cool-season grasses grown in this region vary in their capacity to store high levels of fructans (Table 12). However, management factors such as stubble heights, fertility levels, and grazing management have a greater effect on fructan levels than do inherent species characteristics.

### Laminitis prevention

Laminitis prevention requires management of both animals and pasture forage. To minimize the risk, adopt the following management practices:

- Apply adequate (but not excessive) nutrients—especially N and K—to keep plants growing rapidly.
- Maintain plant height above minimum stubble heights but don’t allow plants to go to seed. Stubble height is especially important in spring and autumn. (Remember, most of the fructans are in the bases of the leaf stems.)
- Introduce horses to lush spring pasture gradually.
- Rotate pastures frequently to avoid regrazing of recently grazed, newly regrowing plants.
- Use grazing muzzles on horses.
- Limit grazing to the morning hours, as plant sugars are higher in the afternoon and evening.
- Limit grazing during times of environmental stress on plants, such as drought.
- Don’t allow horses to graze freshly cut grass stubble. (Sugars can continue to accumulate in forage, even after it is cut.)
- Reduce or eliminate feeding of high-carbohydrate supplements such as grain.
- Test the carbohydrate levels and protein in hay and balance the ration as needed.

**Table 12. Relative fructan (sugar) levels in common pasture species.**

Fructan level	Species
Highest	Perennial ryegrass
	Kentucky bluegrass
	Bentgrass
	Timothy
	Tall fescue
Lowest	Orchardgrass
	Clovers and alfalfa

Sources: Downing and Gamroth, 2007; Fransen and Hudson, 2006; Holechek and Galt, 2004; Shewmaker et al., 2006; Volenec, 1986; Watts, 2008.

## Appendix 7. The Nitrogen Cycle: Formation, Utilization, and Movement in Forages

### Sources of N

Nitrogen (N) is a major required nutrient for forage plants. Forage plants utilize N from one or more of four sources.

- N can be “fixed” by certain forage plants, commonly referred to as legumes. A symbiotic (mutually beneficial) relationship between certain rhizobia bacteria in the soil and single plant root hairs leads to development of nodules on the root. Each nodule can fix organic N if the correct bacteria infect the root hair. Red or pink nodules are actively fixing N. White nodules are considered non-N fixing, while green nodules are dead.

Grasses do not fix N on their own, although some research suggests that certain fungi may aid in fixing small quantities of N. Unfortunately, the amount of N fixed is inadequate to meet the needs of grass plants. Thus, grass must take up N from the other three sources.

- N can be mineralized or released from soil organic matter (OM). In this process, soil bacteria change dead plant matter in the soil to humus and ultimately release both organic carbon and N. Other soil bacteria convert this N into forms that forage plants can take up via their roots.
- N can be obtained from commercial fertilizers.
- N can be obtained from manure and compost.

In all cases, grasses and legumes take up N in only two forms: nitrate ( $\text{NO}_3^-$ , an anion) and ammonium ( $\text{NH}_4^{++}$ , a cation). Both are inorganic. The N fixed by legumes and the N in soil OM are in the organic



Figure 20. Applying most of the needed nutrients in the spring will fuel rapid growth in spring and summer. Photo by Scott Robbins.

form, which must be mineralized by soil bacteria to nitrate and ammonium.

High levels of N in forage can be toxic to livestock. See Appendix 8 (page 44).

### N loss from soil

Nitrate contains N and oxygen (O) and is negatively charged. The negative charge of western Oregon and Washington soils does not provide a location for the negatively charged nitrate to bind. Thus, in the presence of excess soil water ( $\text{H}_2\text{O}$ ), nitrate can be leached from these soils at any time of the year.

Ammonium is positively charged and is composed of N and hydrogen. Negatively charged soil provides many binding sites for the positively charged ammonium N. Thus, ammonium does not directly leach from western Oregon and Washington soils.

In saturated winter soils, N can also be lost through denitrification. In this case, N is volatilized into  $\text{N}_2$  gas and lost to the atmosphere, which is already about 78 percent N.

## Evaluating the need for N application

A goal in western Oregon and Washington pasture management is to provide adequate N to promote desired forage yield and crude protein (CP) concentration without leaching nitrates into the groundwater or accumulating high concentrations of nitrate in forage. This is not an easy balance to maintain, as the need for N changes throughout the growing season and often varies from year to year.

Grasses normally respond to N application with higher yields, as long as no other nutrient is limiting. One easy way to determine whether grasses will respond to N application is to visually evaluate deficiency symptoms.

Look for symptoms on older plant tissue, i.e., tissues near the base of the plant. If N is deficient, the grass will mobilize N from older leaves to newer growing leaves at the top of the plant. Thus, the lower leaves will change from green to yellow, starting at the leaf tip. Under severe N deficiency, older leaves will turn tan or brown and eventually will die when most of the N has been mobilized. See Appendix 9 (page 45) for more information on visual symptoms of nutrient excesses and deficiencies.

Note that canopies with growth older than about 45 days may show similar symptoms due to shading of the lower leaves. After harvesting, monitor the color of regrowth.

## Crude protein levels

Table 13 presents crude protein (CP) concentrations for shorter-lived ryegrasses (Buckley, WA) harvested under an annual five-cutting schedule. All of the ryegrasses were fertilized with 60 lb N/a/cutting. The Buckley site would be considered Puget Lowlands in the Pasture Calendar.

**Table 13. Crude protein concentration (%) of ryegrass by harvest cutting and growth stage over 3 to 6 years in western Washington (Buckley, WA).**

Cutting	Month	Growth stage	Crude protein (%)	
			Annual ryegrass	Perennial ryegrass
1	May	Boot	9.8	10.6
2	June	Early boot	15.5	16.9
3	July	Vegetative	20.6	20.7
4	Aug	Vegetative	22.9	24.0
5	Sep/Oct	Vegetative	23.2	30.3

Source: Fransen, 1999.

**Table 14. Crude protein concentration (%) of tall fescue by harvest cutting and growth stage over 3 to 6 years in western Washington (Puyallup, WA).**

Cutting	Month	Growth stage	Crude protein (%)	
			No N	60 lb N/a/cutting
1	April	Boot	14.0	17.9
2	May	Early boot	12.4	17.1
3	June	Vegetative	11.4	17.0
4	July	Vegetative	12.6	16.2
5	Aug	Vegetative	12.9	15.6
6	Sep/Oct	Vegetative	14.2	15.8

Source: Fransen, 1999.

Table 14 presents CP concentrations for longer-lived tall fescue (Puyallup, WA) harvested under a six-cutting schedule. Tall fescue received no N or 60 lb N/a/cutting. The growing season is longer in Puyallup, and this area would also be considered Puget Lowlands.

## Appendix 8. Nitrates in Forages

Nitrogen in the nitrate form, if at excess levels, can be harmful to livestock. While all animals are at risk of nitrate poisoning, ruminants such as sheep, goats, and cattle are the most commonly affected.

After being taken up by the forage plant, N is quickly converted to nonprotein N (NPN), which consists largely of amino acids and urea. Amino acids combine to form proteins.

When growing grasses are unstressed, the conversion of N into NPN is rapid, resulting in high NPN concentrations. Under greater environmental stress, conversion to NPN is slower and plants accumulate nitrate in the aboveground forage.

Livestock that ingest high-nitrate forage often become sick very quickly and can die within 3 to 4 hours. Inside the rumen, nitrate is converted to nitrite (NO<sub>2</sub>). Nitrite displaces oxygen in the animal's blood hemoglobin to produce methemoglobin. Methemoglobin is unable to transport oxygen, so the animal suffocates.

Most grazing animals normally have only about 1 or 2 percent methemoglobin, but the concentration can quickly rise to about 50 percent and cause death.

Administering methylene blue to sick animals will rapidly reverse methemoglobin to hemoglobin.

Some plants tend to accumulate high levels of nitrate, while others typically contain very small levels. Nitrate accumulation has not been as extensively studied in forage crops as in vegetables. However, we do know in a broad sense which crops tend to be problem accumulators more frequently than others. Table 15 is based on the common understanding of nitrate accumulation potential when supplemental N is provided.

Nitrates can accumulate in plants for several reasons. Among the most common are excess N application, environmental stresses such as drought, and the use of phenoxy herbicides. Nitrates are known to accumulate in both stems and leaves, but the highest concentration is found in stems.

If you suspect forage has been grown under stress with high N application, it is best to test the forage before feeding it to livestock. The potential for nitrate poisoning can be determined by measuring the percentage of nitrate, nitrate-nitrogen, or potassium nitrate in forage. Table 16 provides guidelines for determining the safety or toxicity of forages.

**Table 15. Potential of forage crops and weeds to accumulate nitrate.**

Crops with lower potential	Crops with intermediate potential	Crops/weeds with higher potential
Meadow fescue, smooth brome grass, crested wheatgrass, timothy	Orchardgrass, perennial ryegrass, alfalfa, annual ryegrass, tall fescue, true clovers	Oats, barley, Canada thistle, lambsquarter, wheat, sorghum, corn, stinging nettle, redroot pigweed

Sources: Crawford and Kennedy, 1960; Pfister, 1988.

**Table 16. Guidelines for forages with nitrates.**

Nitrate		Nitrate N	Potassium nitrate		
(%)	(ppm)	(%)	(%)	(ppm)	
<0.44	<1,000	0.10	<7,170	<0.72	Safe for feeding
0.44–0.66	1,000–1,500	0.10–0.15	7,710–10,758	0.72–1.08	Safe for all nonpregnant animals
0.66–0.88	1,500–2,000	0.15–0.20	10,758–14,344	1.08–1.43	Safe if <50% of diet DM
0.88–1.54	2,000–3,500	0.20–0.35	14,344–25,102	1.43–2.51	Safe if <35% of diet DM
1.54–1.76	3,500–4,000	0.35–0.40	25,102–28,688	2.51–2.87	Safe if <25% of diet DM. Do not feed to pregnant animals.
>1.76	>4,000	>0.40	>28,688	>2.87	Toxic. May cause abortion, respiratory depression, and death.

Source: Fransen, 1991.

## Appendix 9. Symptoms of Nutrient Excesses and Deficiencies

**Table 17. Visual symptoms of nutrient excesses and deficiencies of common western Oregon and Washington grasses and legumes.**

Color change	Location of discoloration	Growth effects
<b>Yellow</b>	<b>Old tissue</b>	<b>Stunted top growth</b>
Nitrogen (D)	Nitrogen (D)	Nitrogen (D)
Magnesium (D)	Potassium (D)	Phosphorus (D)
Sulfur (D)	Magnesium (D)	Magnesium (D)
Chlorine (D)	Sulfur (D)	Copper (D)
Iron (D)	Chlorine (E)	Manganese (D)
Manganese (D)		Aluminum (E)
Zinc (D)	<b>Young tissue</b>	<b>Stunted root growth</b>
	Copper (D)	Copper (E)
<b>Light green</b>	Iron (D)	Phosphorus (D)
Sulfur (D)	Manganese (D)	Aluminum (E)
Nitrogen (D)	Zinc (D)	
Chlorine (D)		<b>Early maturity</b>
Iron (D)	<b>Between veins</b>	Nitrogen (D)
Manganese (D)	Magnesium (D)	
Zinc (D)	Iron (D)	<b>Slow growth</b>
Magnesium (D)	Manganese (D)	Nitrogen (D)
	Zinc (D)	Phosphorus (D)
<b>Brown</b>	<b>Leaf margins</b>	<b>Growing points abnormal</b>
Nitrogen (D)	Potassium (D)	Boron (D)
Calcium (D)		Copper (D)
Boron (E)	<b>Begins at leaf tip</b>	<b>Plants spindly</b>
	Nitrogen (D)	Nitrogen (D)
<b>Purplish</b>	Calcium (D)	
Phosphorus (D)	Boron (E)	
Aluminum (E) (stems)	Chlorine (E)	
	Aluminum (E) (death)	
<b>Dark green</b>	Potassium (D) (legumes; yellow spots)	
Nitrogen (E)		
Aluminum (E)	<b>Along midrib</b>	
	Nitrogen (D)	
	<b>Striping in stem nodes</b>	
	Zinc (D)	
	<b>Leaf edges appear "burned"</b>	
	Potassium (D)	
	Chlorine (E)	

E = excess; D = deficiency

## Nutrient interactions

In some cases, excess amounts of one nutrient may lead to deficiencies of other nutrients. See Table 18.

**Table 18. Nutrient interactions.**

Excess	Resulting deficiency symptoms
Phosphorus	Zinc, iron, manganese, calcium
Potassium	Magnesium, calcium
Calcium	Magnesium, potassium
Magnesium	Calcium, potassium
Manganese	Brown spots surrounded by a chlorotic zone on leaves
Copper	Iron, molybdenum
Nitrogen	Magnesium
Magnesium	Iron
Iron	Bronzing of leaves with tiny brown spots
Zinc	Iron

## Appendix 10. Alternative Forage Crops

Alternative crops are forages grown either to extend the normal grazing season or to supplement livestock during the fall and winter when pasture growth is minimal. For example, a forage may be grown to be available for grazing in the summer when dryland pastures go dormant. A crop may also be planted in the late summer or fall for grazing in late winter prior to the time when permanent pasture is available. Depending on the plant species and growth stage, alternative crops can provide 2 to 8 tons of dry matter per acre for grazing.

Most alternative forages are annuals. Some typical crops include sorghum-Sudan grass hybrids, annual ryegrass, cereals (triticale, barley, rye, wheat, and oats), forage chicory, and brassicas (kale, turnips, and rape; Figure 21). Forage plantain—a perennial—can also be used as an alternative crop.

Some of these crops don't grow well in cool temperatures, so investigate details before selecting a crop. For example, Sudan grass and sorghum-Sudan crosses are warm-season annuals and do not perform well if planted early in the spring. Not all crops are suitable for all areas.

Alfalfa, red clover, and other legumes are often used as alternative crops even though they are perennials. They are most often used during late summer or fall in dryland areas. Bloat is a concern when grazing legumes, so precautions must be taken to prevent loss of livestock.



Figure 21. Alternative forage crops, such as brassicas, can provide forage during times of the year when grass growth is minimal. Photo by Scott Robbins.

Alternative forage crops typically are sown into a prepared seedbed and timed to grow and be available when a seasonal forage shortage is expected. Therefore, the land used for an alternative forage crop is separate from perennial pasture land. Some alternative forages can be planted as part of a pasture mix, but in this case they are not a true alternative crop; the rules for grazing a perennial pasture must apply.

An excellent website for alternative forage crops is <http://AgGuide.agronomy.psu.edu/default.html>. Information specific to western Oregon and Washington is available in EB 1870, *Pasture and Hayland Renovation for Western Washington and Oregon*.



## Appendix 11. Endophyte Toxins in Forage

Endophyte is a fungus that lives inside a grass plant. The relationship between the grass and endophyte is symbiotic; they both benefit. Infected plants can have increased growth, increased drought tolerance, and resistance to certain insects. Certain species of endophyte, however, produce toxins that are harmful to livestock.

Endophytic fungi are associated with both forage and turf types of tall fescue (*Schedonorus phoenix* [Scop.] Holub) and perennial ryegrass (*Lolium perenne* L.).

These fungi are from the genus *Epichloë*. The most well-known are *Epichloë coenophiala* (formerly *Neotyphodium coenophialum*) and *Epichloë festucae* var. *lolii* (formerly *Neotyphodium lolii*). Tall fescue hosts *E. coenophiala*, while perennial ryegrass hosts *E. festucae* var. *lolii*.

Ergovaline, a toxin (Figure 22), is produced by both *E. coenophiala* (in tall fescue) and *E. festucae* var. *lolii* (in perennial ryegrass). Indole-diterpenes, such as lolitrem B, are associated with ryegrass staggers. These compounds are produced in perennial ryegrass by *E. festucae* var. *lolii*.

Because turfgrass breeders select for the qualities associated with endophyte, some cool-season turfgrass varieties contain high levels of endophyte.

Thus, lawn and sport field grass varieties should not be used for pastures. Fields to be used for pasture or hay must be planted with endophyte-free forage-type varieties. These varieties should be safe to graze or cut for hay.

“Livestock friendly,” or nontoxic, strains of endophytes (also called novel endophytes) are being developed for forage varieties of grasses. These endophytes provide the plant with positive attributes, but do not produce toxins that are harmful to livestock. Forage grass varieties infected with these endophytes are now commercially available.

The endophyte is transmitted by seed, and its entire life cycle takes place inside plant tissues. A plant does not become infected from its neighbors. Therefore, a stand of a noninfected variety will remain noninfected. If a noninfected pasture is overseeded with an infected variety, only the new plants will be infected.

Since endophyte infection does not affect the appearance of grass plants, its presence can be detected only by laboratory analysis. Questionable fields can be sampled and tested for the presence of toxins. More information on endophyte and the effects on livestock can be found in EM 9156, *Endophyte Toxins in Grass and Other Feed Sources: Risks to Livestock*.

## For More Information

- Agrimet. U.S. Bureau of Reclamation. <https://www.usbr.gov/pn/agrimet/>
- AgWeatherNet. Washington State University. <https://weather.wsu.edu/?p=88650>
- Early Spring Forage Production for Western Oregon Pastures*. EM 8852, Oregon State University. <https://catalog.extension.oregonstate.edu/em8852>
- Endophyte Toxins in Grass and Other Feed Sources: Risks to Livestock*. EM 9156, Oregon State University. <https://catalog.extension.oregonstate.edu/em9156>
- Estimating Soil Moisture by Feel and Appearance*. Program Aid Number 1619, USDA.
- Fertilizing with Manure*. PNW 533, Washington State University. <https://catalog.extension.oregonstate.edu/pnw533>
- How Pasture Plants Grow*. PM 1791, Iowa State University. <https://store.extension.iastate.edu/Product/5366>
- Pasture and Hayland Renovation for Western Washington and Oregon*. EB 1870, Washington State University. <http://cru.cahe.wsu.edu/CEPublications/eb1870/eb1870.pdf>
- Planning and Managing Irrigation*. Fact Sheet #14, Tips for Small Acreages in Oregon, Washington County SWCD.
- PNW Weed Management Handbook*. <https://pnwhandbooks.org/weed>
- Post-Harvest Soil Nitrate Testing for Manured Cropping Systems West of the Cascades*. EM 8832-E, Oregon State University. <https://catalog.extension.oregonstate.edu/sites/catalog/files/project/pdf/em8832.pdf>
- Soil Management for Small Farms*. EB 1895, Washington State University.
- Soil Test Interpretation Guide*. EC 1478, Oregon State University. <https://catalog.extension.oregonstate.edu/ec1478>
- Timing of Nitrogen Fertilizer for Oregon Pastures*. Circular No. L&F 102b, Oregon State University, Douglas County Extension.

## References

- Bedell, T. 1986. *Managing Pastures in Western Oregon*. EC 1077, Oregon State University.
- Crawford, R. and W. Kennedy. 1960. Cornell University Agricultural Experiment Station Misc. Bull. 37.
- Downing, T. and M. Gamroth. 2007. *Nonstructural Carbohydrates in Cool-season Grasses*. SR 1079-E, Oregon State University.
- Fransen, S. 1991. Controlling nitrates in forages. In *Proceedings of NW Dairy Short Course*. Washington State University Cooperative Extension.
- Fransen, S. 1999. Unpublished data from Washington State University Dairy-Forage Center, Buckley, WA.
- Fransen, S. 2000. Proper stubble height for forage grasses. *British Columbia Dairy Leader* (Spring):44-45.
- Fransen, S. and T. Griggs. 1998. Grass tillers—do they count? *The Progressive Dairyman* 12(4):23-24.
- Fransen, S., T. Griggs, and R. Dovel. 1998. September—a critical month for forages. *The Progressive Dairyman* 12(1):18-19.
- Fransen, S. and T. Hudson. 2006. Post-harvest management of timothy hay for surviving another 100 years drought. In *Western Alfalfa and Forage Conference*. D. Putnam, G. Shewmaker, and S. Orloff (eds.). University of California. <http://alfalfa.ucdavis.edu>
- Gardner, F. and W. Loomis. 1953. Floral induction and development in grasses. *Plant Physiology* 28:201-217.
- Holechek, J. and D. Galt. 2004. More on stubble height guidelines. *Rangelands* 26(4):3-7.
- Hunter, B. 1906. *Forage-Crop Practices in Western Oregon and Washington*. Farmers Bulletin 271, USDA.
- Mayland, H., L. Greene, D. Robinson, and S. Wilkinson. 1990. Grass tetany: A review of Mg in the soil-plant-animal continuum. In *Proceedings of the Pacific Northwest Animal Nutrition Conference*.
- Neibling, H., M. Bohle, and C. Falen. 2010. Chapter 6: Principles of pasture irrigation. In *Pasture and Grazing Management in the Northwest*. G. Shewmaker and M. Bohle (eds.). PNW 614, University of Idaho. <http://www.westernsare.org/Learning-Center/SARE-Project-Products/Books-Case-Studies-Guidebooks-and-Manuals/Pasture-and-Grazing-Management-in-the-Pacific-Northwest>

- Pfister, J. 1988. Nitrate intoxication of ruminant livestock. In *The Ecology and Economic Impact of Poisonous Plants on Forage Production*. L. James, M. Ralphs, and D. Nielsen (eds.). Westview Press, Boulder, CO.
- Pirelli, G. and S. Fransen. 2016. *Pasture Management: Understanding Plant and Root Growth in the Fall*. Oregon State University Extension.
- Shewmaker, G., H. Mayland, C. Roberts, P. Harrison, N. Chatterton, and D. Sleper. 2006. Daily carbohydrate accumulation in eight tall fescue cultivars. *Grass and Forage Science* 61:413–421.
- Sprague, V. and J. Sullivan. 1950. Reserve carbohydrates in orchardgrass clipped periodically. *Plant Physiology* 25:92–102.
- Stuckey, I. 1941. Seasonal growth of grass roots. *American Journal of Botany* 28:486–491.
- Sullivan, D., C. Cogger, A. Bary, and S. Fransen. 2000. Timing of dairy manure applications to perennial grass on well drained and poorly drained soils. *Journal of Soil and Water Conservation* 55:147–152.
- USDA NRCS. 1994. *The Phosphorus Index*. Oregon Technical Note, Agronomy No. 26.
- Volenc, J. 1986. Non-structural carbohydrates in stem base components of tall fescue during regrowth. *Crop Science* 26:122–127.
- Watts, K. 2008. Carbohydrates in forage: What is safe grass? In *Proceedings, Kentucky Equine Research. Advanced Management of Gastrointestinal and Metabolic Diseases*. Lexington, KY.
- Yang, J., C. Matthew, and R. Rowland. 1998. Tiller axis observations for perennial ryegrass (*Lolium perenne*) and tall fescue (*Festuca arundinacea*): Number of active phytomers, probability of tiller appearance, and frequency of root appearance per phytomer for three cutting heights. *New Zealand Journal of Agricultural Research* 41:11–17.