USDA Agricultural Research Service
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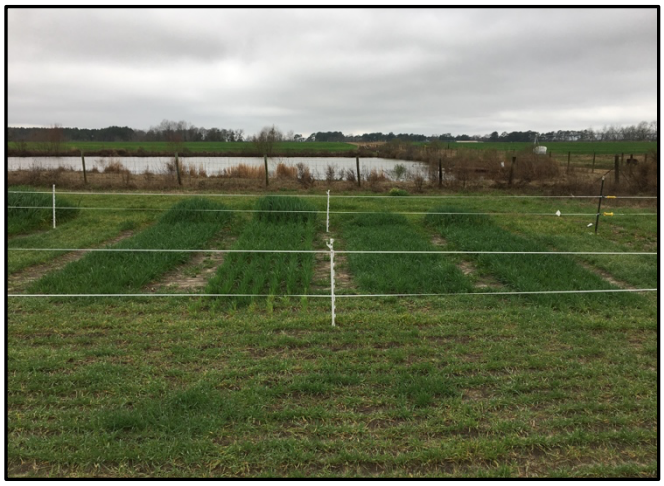
Physiology of Grazed Cool-Season Grasses

U.S. Dairy Forage Research Center

Introduction

Grazing-based dairy producers are often faced with a complicated question. Should pasture management be based on what's best for the animal or what's best for the grass? While both considerations are important, many will argue that deference should be given to the grass because it establishes the foundation for meeting livestock nutritional requirements. Grazing-based producers benefit most from having a uniform and predictable seasonal distribution of production. While this remains a highly desirable goal, it is probably unattainable on a practical basis given year-to-year variability within a host of weather-related factors, such as precipitation, temperature, drought, flooding, and snow cover. However, good pasture management can mitigate many problems related (primarily) to insufficient grass availability. A discussion of plant growth and structure and the way these characteristics are affected by weather and grazing management may be helpful.



Research plots in Georgia where researchers are evaluating the physiological impacts of grazing on cool season grasses.

Photosynthesis

Growth processes for plants depend on supplies of carbohydrates derived from photosynthesis. The sun's energy is harnessed to produce carbohydrates (sugars) from carbon dioxide. These carbohydrates are subsequently used as substrates for necessary respiration, plant growth (more leaves and tillers) and keeping the plant alive during times of stress (winter or drought).

Most of the grasses and legumes used in dairy grazing operations throughout the northeastern and north-central United States are cool-season forages, meaning they grow best under optimum temperatures of 68 to 77ºF. Cool-season forages are not well adapted to warmer temperatures, such as those observed commonly throughout the southeastern or southwestern states. This lack of adaptability to heat or temperature stresses also can contribute to an often-observed 'summer slump' for cool-season pastures, even in areas where they are climatically adapted. Cool-season grasses store their carbohydrate reserves in stem or tiller bases, stolons, and rhizomes, primarily as fructan. Knowing the storage site of these carbohydrate reserves for specific grasses is important for good pasture management. For example, Kentucky bluegrass is more tolerant of close, repetitive defoliation because its storage organ is the rhizome, which lies immediately under the soil surface. This partially explains why Kentucky bluegrass is commonly used as a turfgrass throughout much of the country, and why continuously overgrazed pastures often become Kentucky-bluegrass dominant over time. In contrast, orchardgrass and tall fescue generally are less tolerant of close or repetitive defoliation because fructan is stored in upright stem or tiller bases.

The significance of this concept can be emphasized in a rather unconventional way. A popular textbook written by Dr. Peter Van Soest (Cornell University) includes a graph (see Figure 1; Mowat et al., 1965; Van Soest, 1982) depicting the digestibility of orchardgrass leaves and stems as a function of maturity (harvest date). While the graph generally shows the predictably greater digestibility for leaves compared to stems, this is clearly untrue in the relatively early stages of reproductive development (in this figure, late-May). This occurs because the removal of stem tissue contains significant carbohydrate reserves, which are highly digestible, and the structural portion of the stem has not yet matured or lignified enough to significantly depress digestibility. It must be emphasized that this is not meant to justify close defoliation of stem or tiller bases in these grasses; doing so can prove to be quite costly with respect to future regrowth and plant persistence. Rather, the illustration is meant only to emphasize the positioning of growth reserves in erect cool-season forages and to encourage consistent diligence in maintaining a sufficient residual sward height following any type of defoliation (grazing or mechanical).

Effects of Grazing

After defoliation by grazing livestock, plants utilize two sources of energy to recover and regrow. These include:

- using existing or residual leaves to generate new carbohydrates via photosynthesis or
- mobilizing stored carbohydrates.

The consequences of inadequate and adequate grazing residual are depicted in Figure 2. When adequate residual is left after grazing, photosynthesis within the remaining leaves produces most of the carbohydrates needed for new leaves (Figure 2, right). However, when there is inadequate residual left after grazing, the plant must rely on stored carbohydrates to generate regrowth (Figure 2, left). Generally, plants would prefer to generate new leaf tissue by producing carbohydrates from old leaves via photosynthesis rather than by mobilizing stored carbohydrates. Doing so also shortens the recovery time required before cattle can graze the same pasture during the next grazing cycle.

In contrast, shorter residual sward heights may:

- increase the length of rest periods required between grazing events,
- change the species composition within mixed-species pastures, or
- encourage encroachment of undesirable weeds.

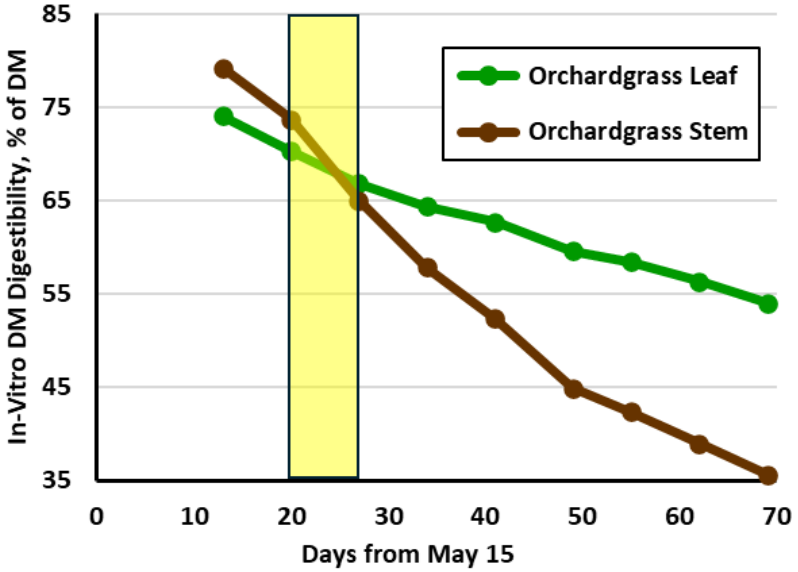


Figure 1. In vitro digestibility of DM for leaf and stem tissues of orchardgrass as a function of harvest date. Data represent the mean of two cultivars grown over three years in Canada. The yellow shaded box represents the early flower stage of growth for the two cultivars [adapted from Mowat et al. (1965); Van Soest (1982)].

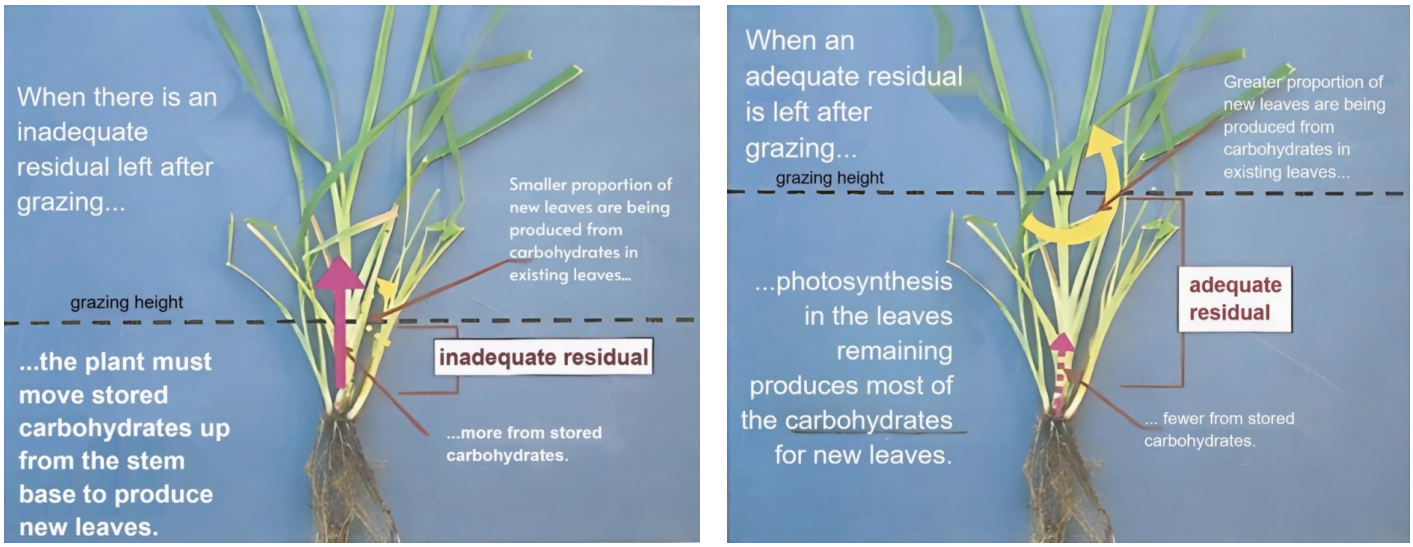


Figure 2. Depiction of inadequate (left) and adequate (right) residual after defoliation by grazing.

While the previous discussion explains general concepts of defoliation and growth reserves for erect-growing cool-season grasses, there are some inherent differences between species. In work conducted in south-central Wisconsin (Alber et al., 2014), meadow fescue and orchardgrass were grazed at vegetative (12-inch) or mature (20-inch) stages of development to either an estimated 50 or 100% removal by dairy heifers within short, 8- to 24-hour periods.

In both years of the trial, which differed significantly with respect to precipitation, orchardgrass produced more above-ground biomass than meadow fescue. Furthermore, orchardgrass exhibited no relationship between the applied grazing treatments and below-ground growth, suggesting it was more defoliation tolerant or relatively insensitive to defoliation management compared to meadow fescue. In other words, results of this study suggest that orchardgrass is more tolerant of overgrazing than meadow fescue. This was attributed to a greater leaf sheath-to-stem ratio that permitted continued photosynthesis sufficient to support regrowth. Meadow fescue needed to draw more heavily on stored growth reserves. Regardless of species, the combination of a mature (20-inch) grazing initiation height coupled with 100% removal maximized the grazing interval, which was roughly 50% longer in a below-average precipitation year (Figure 3). Except for the 12-inch/50% removal treatment combination, grazing intervals (rest periods) generally were longer for meadow fescue, averaging about 6 extra days for recovery across all other grazing treatments and precipitation years.

A broader investigation of these concepts was conducted over 2 years (2009-2010) at Prairie du Sac, Wisconsin (Brink et al., 2013). In that experiment, meadow fescue, orchardgrass, quackgrass, and reed canarygrass were subjected to two grazing approaches to assess effects of residual sward height on subsequent regrowth. One approach was to initiate grazing at a 13-inch sward height and then allow 1,000-lb dairy heifers to graze to a 1, 3, or 6-inch residual sward height, which usually required about 8 hours. Heifers were then returned to these paddocks when forages had recovered to the 13-inch initiation height, and the process repeated. The second approach was to initiate grazing at a greater 19-inch sward height and, using similar procedures, terminate grazing at 2, 5, or 9-inch residual sward heights.

These approaches to grazing were intended to simulate or mimic management-intensive grazing and mob-grazing management styles, respectively. In management-intensive grazing systems, grasses are typically grazed at a vegetative stage to a predetermined residual sward height. Mob- or high-density grazing allows grasses to reach a more mature state followed by grazing at a high stocking density. Oftentimes, this approach results in some portion of the forage being refused because of advanced maturity or trampling by livestock.

On a practical basis, residual sword heights were selected to remove about 50, 75, or 100% of the

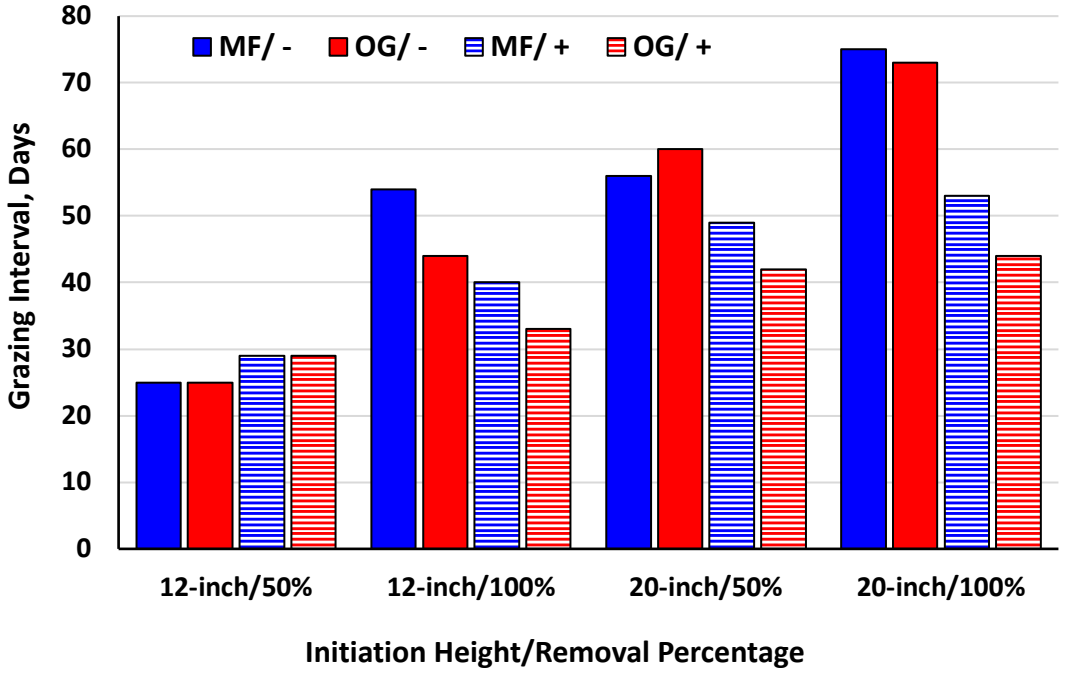


Figure 3. Grazing intervals for meadow fescue (MF, blue bars) and orchardgrass (OG, red bars) for 12 and 20-inch grazing initiation heights and 50 or 100% removal by dairy heifers. Solid bars represent a below-average (-) precipitation year, while patterned-filled bars denote an above-average (+) precipitation year [adapted from Alber et al. (2014)].

available forage, regardless of the grazing-management approach. Throughout the summer months, 2009 was a below average precipitation year, while 2010 was both warmer and wetter than normal. The number of grazing events and grazing intervals, as well as the amount of forage harvested by grazing livestock during each grazing event are summarized for meadow fescue and orchardgrass during dry (Table 1) and wet (Table 2) years. Key findings in this uniquely constructed experiment were:

- Generally, orchardgrass was more productive than meadow fescue and tiller density was less affected by below-normal precipitation, even under aggressive (~100%) defoliation.
- As expected, the more favorable growing conditions in 2010 resulted in more harvested forage on both a per-event and per-year basis compared to those obtained the previous drier year.
- For either management approach, the consequences of grazing to a short residual sward height (essentially, 100% removal) were primarily longer grazing intervals and generally fewer grazing events. These trends were strongly exacerbated under dry conditions.
- Close defoliation delayed growth the following spring. Regardless of grazing management approach, each increase in removal from 50 to 75, and then to 100% resulted in an additional week delay in reaching the targeted grazing initiation height the next spring. This response can be attributed to the depletion of growth reserves, which subsequently reduced plant vigor.
- Under the management intensive system, tiller densities of meadow fescue, quackgrass, and reed canarygrass were reduced by close defoliation during the drier year (Figure 4). However, orchardgrass proved more resilient. Under the mob-grazing system, reductions in tiller density were observed only for quackgrass and reed canarygrass in response to close defoliation. With better growing conditions the following year, tiller densities for all forages were largely unaffected by residual sward height (data not shown).
- When grass is allowed to mature before it is mob-grazed, there are fewer rotations and annual yield often decreases. Furthermore, the potential for wasted feed increases and forage nutritive value declines as a typical

Table 1. Responses to residual sward height for meadow fescue and orchardgrass in a drier than normal year (2009) at Prairie du Sac, WI [adapted from Brink et al. (2013)].

	Meadow Fescue				Orchardgrass			
Residual Height[1]	**Grazing Events**	**Grazing Interval**	**Forage Grazed/ Event**	**Forage Grazed/ Year**	**Grazing Events**	**Grazing Interval**	**Forage Grazed/ Event**	**Forage Grazed/ Year**
Inches	*#*	*Days*	*--- lbs DM/acre ---*		*#*	*Days*	*--- lbs DM/acre ---*	
Management Intensive Grazing (13-inch Initiation Height)								
1 (100%)	4	51	1016	4054	4	44	1265	5061
3 (75%)	5	34	793	3947	6	32	927	5533
6 (50%)	6	25	499	3012	6	25	740	4428
Mob Grazing (19-inch Initiation Height)								
2 (100%)	3	74	1533	4589	3	73	1648	4945
5 (75%)	3	63	1372	4125	3	62	1550	4651
9 (50%)	3	57	1123	3377	3	60	1292	3885

[1] *Residual sward heights approximate 100, 75, and 50% removal.*

Table 2. Responses to residual sward height for meadow fescue and orchardgrass in a wetter than normal year (2010) at Prairie du Sac, WI [adapted from Brink et al. (2013)].

	Meadow Fescue				Orchardgrass			
Residual Height[1]	**Grazing Events**	**Grazing Interval**	**Forage Grazed/ Event**	**Forage Grazed/ Year**	**Grazing Events**	**Grazing Interval**	**Forage Grazed/ Event**	**Forage Grazed/ Year**
Inches	*#*	*Days*	*--- lbs DM/acre ---*		*#*	*Days*	*--- lbs DM/acre ---*	
Management Intensive Grazing (13-inch Initiation Height)								
1 (100%)	4	40	1497	6005	5	33	1354	6754
3 (75%)	6	29	998	5996	6	31	1105	6638
6 (50%)	7	29	775	5417	7	29	891	6255
Mob Grazing (19-inch Initiation Height)								
2 (100%)	3	53	2067	6219	3	49	2602	7805
5 (75%)	3	49	1372	4116	4	44	1675	6763
9 (50%)	3	48	1345	4045	4	42	1809	7235

[1] *Residual sward heights approximate 100, 75, and 50% removal.*

function of plant maturity and/or aging. Because of the decrease in nutritive value, research suggests that mob-grazing is not a good fit for dairy herds and is better suited for beef applications. It also can be a useful management practice to address specific situational needs, such as preparing pastures for renovation or frost seeding.

Management Considerations during Drought

During dry weather, producers should watch for early signs of moisture stress. During stress, plants are more dependent on stored carbohydrates to maintain turgor pressure within the leaves as well as for growth. As partially suggested by the results

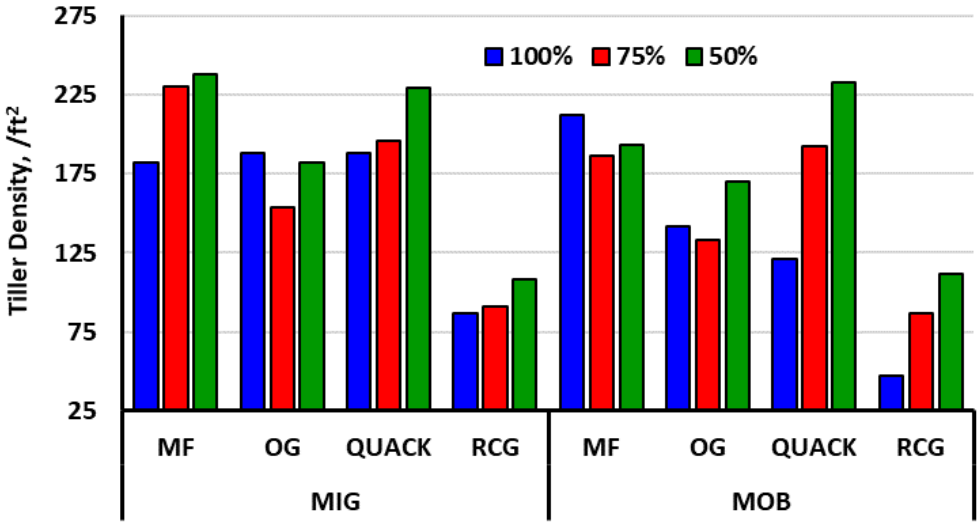


*Figure 4. Tiller densities for meadow fescue (**MF**), orchardgrass (**OG**), quackgrass (**QUACK**), and reed canarygrass (**RCG**) measured after approximately 50, 75, and 100% removal under two simulated management systems [management intensive (**MIG**) or mob (**MOB**)] in a below normal precipitation year. Tiller densities were largely unaffected by grazing treatment during the subsequent above-normal precipitation year [adapted from Brink et al. (2013)].*

shown in Figure 3, increasing the targeted residual height of the grazed plants and lengthening the rest periods between rotations can be helpful in maintaining healthy pastures.

Under conditions of drought stress, producers should resist the temptation to overgraze, which will potentially harm pastures and will certainly delay regrowth once drought conditions subside. Rather than overgrazing, consider using supplemental harvested forages to limit stress on pastures during periods of drought. These supplemental forages can be offered in a drylot or feedlot facility with livestock completely removed from all pasture paddocks. However, if a separate feeding area is not available, consider using a sacrifice pasture or paddock. Remove all animals from all other pasture paddocks except for this specific sacrifice area and feed them hay, silage, or other feedstuffs in that location only. Forage plants in this sacrifice paddock may die from overgrazing and/or livestock traffic, but the rest of the pasture will benefit greatly and respond positively once the drought subsides.

Summary

- Perennial cool-season grasses depend on a supply of carbohydrates that are derived from photosynthesis for respiration, growth, and survival during times of stress (drought or winter dormancy).
- Most erect-growing cool-season grasses store growth reserves in the tiller or stem bases.
- After defoliation, regrowth is supported by two sources of energy:
  - using residual leaf tissue to generate new carbohydrates (photosynthesis), or
  - mobilizing stored carbohydrates.
- Use of residual leaf tissue to generate carbohydrates is preferred, and shortens recovery time between grazing events, but also requires close management of residual stubble height.
- Removal of too much forage in any grazing event may compromise forage production, regrowth, recovery times, plant health, or plant persistence. Individual forage species may respond differently to overgrazing, and these differences may be exacerbated under stressful (most commonly, droughty) growing conditions.
- During drought, avoid overgrazing by offering supplemental forages and feedstuffs in a dedicated drylot or on a sacrifice pasture or paddock until the droughty conditions subside.

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