USDA Agricultural Research Service
U.S. DEPARTMENT OF AGRICULTURE

Effects of Canopy Structure on Intake of Perennial Cool-Season Grasses

U.S. Dairy Forage Research Center

Introduction

Numerous research studies have attempted to establish the relationships between sward structure of perennial cool-season grass pastures and the subsequent voluntary intake by grazing livestock. Many of these efforts have emphasized the use of perennial ryegrass due to its productivity, forage quality, and prevalence throughout major grassland regions of the world.

Within these studies, several sward characteristics have been related positively with the dry matter (**DM**) intake of grazed forages. A partial list includes sward surface height, leaf blade length, sward bulk density (especially as sward height declines), leaf bulk density, and stems with low tensile strength. In addition, it is widely understood that the voluntary DM intake of harvested forages is negatively associated with concentrations of neutral-detergent fiber (**NDF**) but positively associated with the digestibility of that NDF (**NDFD**).

The negative effects of NDF on voluntary intake are normally associated with rumen fill, where plant cell walls must be broken down to reduce their volume and clear space for additional intake. Comparatively few studies attempting to relate sward structure with the voluntary intake of grazing dairy cattle have included the erect-growing, cool-season grasses commonly used in grazing-based dairy operations throughout North America. This research gap has been partially addressed in two recent studies.

Relevant Studies

A two-year project (2004-2005) conducted at Arlington, Wisconsin, evaluated the seasonal vertical distribution of DM for a variety of cool-season grasses (Brink et al., 2007). In that experiment, when leaf height reached 10 inches, forages were sampled in three layers:

Holstein dairy heifers grazing perennial cool-season grasses.

- 4 to 6 inches
- 6 to 8 inches
- 8 to 10 inches

Pasture intake is normally associated positively with available forage, where available forage is closely linked to canopy density. As mentioned previously, another factor determining voluntary intake is the concentration of NDF within the grazed forage. This is relevant because structural plant fiber (typically measured as NDF) contributes volume within the rumen. Cell walls must be digested or broken down to alleviate this restriction on voluntary intake. To evaluate the relationship between canopy structure and NDF, the NDF concentration of each canopy layer also was determined.

Differences in canopy layer densities in the spring were most evident during 2004 when there was above average precipitation, as well as warmer soil temperatures compared to 2005. Quackgrass exhibited the greatest canopy density in the 8- to 10-inch layer, while Kentucky bluegrass and perennial ryegrass had the greatest densities at the 4- to 6-inch layer. Although the canopy density at the 4- to 6-inch layer for quackgrass was numerically less than Kentucky bluegrass and perennial ryegrass, it did not differ statistically.

Orchardgrass and meadow fescue had the poorest canopy densities at the 4- to 6-inch layer during the spring assessment of 2004. However, with below-normal precipitation that was observed the following spring, most differences in canopy density were undetectable. A clear pattern was observed across both evaluation years, indicating a shift toward greater densities in the lower, 4- to 6-inch layer in the fall. This response was likely due to decreased daylength and increased tillering. Tall fescue is widely known to be especially suitable for fall-stockpiling. This was evident in comparisons with other species as it exhibited particularly high canopy densities in the 4- to 6-inch layer during fall assessments.

As stated previously, available forage and canopy density are important components regulating intake by grazing dairy cows. However, NDF concentrations within these forages generally, and within individual canopy layers specifically, also may be important. Figure 1 illustrates two-year averages for NDF in various canopy layers of orchardgrass, tall fescue, and meadow fescue. Although a popular forage, perennial ryegrass lacked sufficient forage production in the fall of 2004, and (dry) spring and summer of 2005 to permit appropriate sampling. Two points can be noted from this graphic:

- NDF concentrations were greatest in the 4- to 6- inch canopy layer and declined at more elevated layers.
- NDF concentrations for meadow fescue were consistently less than observed for orchardgrass or tall fescue.

Frequently, meadow fescue has been observed in other experiments to exhibit lower concentrations of NDF and greater NDF digestibility (NDFD) than other similar, erect-growing cool season forages.

Regardless of season or species, differences in NDF across canopy layers were generally ≥ 5 percentage units and were significant enough in scope to have tangible effects on intake. This suggests a lower intake potential as forages are grazed to shorter residual canopy heights; however, this must be juxtaposed against the differences among species in canopy densities observed with good precipitation, as well as the noticeable trend for greater canopy densities at the 4- to 6-inch layer across most species in the fall.

Relationships Between Sward Structure and Herbage Intake

To further address this research gap, a two-year experiment (2007-2008) was conducted at Prairie du

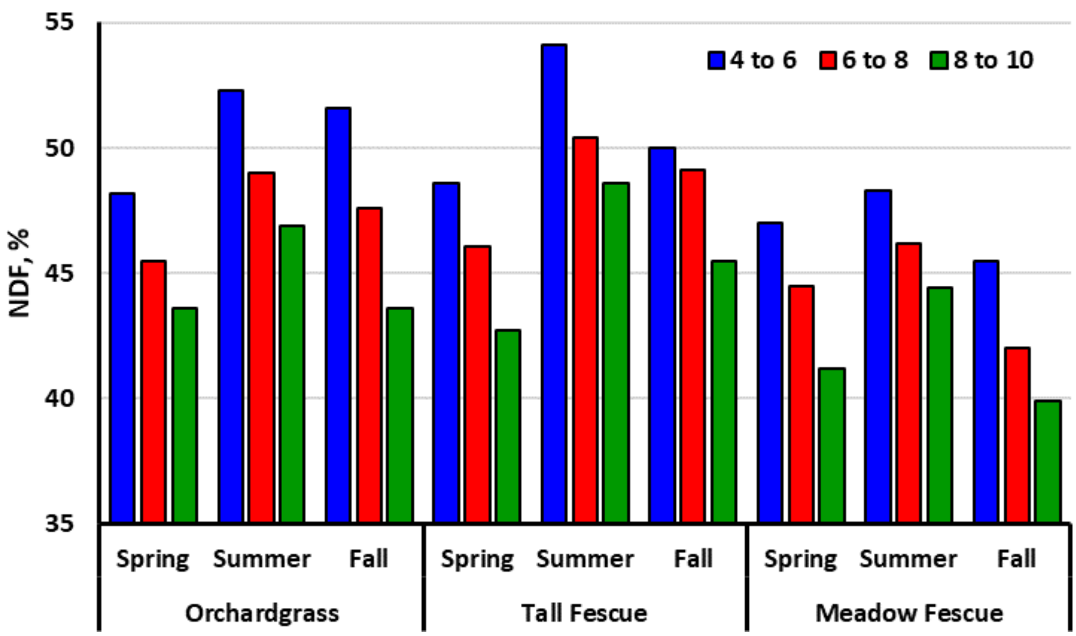

Figure 1. Two-year mean concentrations of NDF within three canopy layers (4 to 6, 6 to 8, and 8 to 10 inches) for three common cool-season forages [adapted from Brink et al. (2007)].

Sac, Wisconsin (Brink and Soder, 2011). Meadow fescue, orchardgrass, quackgrass, and reed canarygrass were grazed during spring, summer, and fall at a vegetative growth stage (3 to 4 collared leaves, but generally before any evidence of stem elongation) for 24 hours by 1,000-lb Holstein dairy heifers to assess any effects of sward-structure characteristics on voluntary herbage intake. For this experiment, heifers were allotted twice their expected DM intake daily, which was set at 24 lbs DM/heifer. Sward structure characteristics are summarized in Table 1.

In assessing these results, it is important to remember that each seasonal grazing event was generally initiated at an immature (vegetative) stage of growth. Under these conditions, and despite differences in pre-grazed height and available forage, forage intake was not generally affected by forage species. For the two seasonal evaluations in which forage removal differed across species, weather-related factors may have affected results. In these cases, the primary determinants of forage intake were leaf and stem bulk densities and their distribution through the sward. Leaf bulk density was positively associated with forage intake, while the bulk density of stem tissue had the opposite effect.

The other possible influence on forage intake includes concentrations of NDF and its associated digestibility (NDFD). In this study, NDF was not strongly influenced by species at vegetative growth stages but varied with seasonal evaluation (Figure 2). Although all forages were grazed at a vegetative state, it is not surprising that NDF varied between seasons. Numerous research studies have related ambient temperature positively with deposition of structural plant fiber (NDF). Concentrations of NDF averaged across all forage species were lower in (cooler) spring assessments than during summer (43.5 vs. 52.9%; Figure 2). Sometimes this can be difficult to demonstrate in field studies because cooler spring temperatures are often confounded with reproductive (stem) development for most erect,

Table 1. Sward structure characteristics of meadow fescue, orchardgrass, quackgrass, and reed canarygrass, as well as the forage removal by grazing Holstein heifers. Herbage removal did not differ statistically among forage species in four of the six seasonal evaluations, and data are grouped for those evaluations to simplify presentation of results [adapted from Brink and Soder (2011)].

Forage	Pre-graze Height	Available Forage[1]	Leaf Bulk Density	Forage Removed
	Inches	*lbs DM/acre*	*lbs DM/ft^3*	*lbs DM/acre*
Mean (four seasons where forage removal was similar among forage species)				
Meadow Fescue	11.7	1495	0.023	444
Orchardgrass	13.1	1435	0.022	465
Quackgrass	11.4	1401	0.024	414
Reed Canarygrass	14.6	1849	0.026	455
Fall 2007				
Meadow Fescue	20.9	2343	0.055	989
Orchardgrass	25.2	2388	0.061	882
Quackgrass	18.9	1827	0.044	864
Reed Canarygrass	21.3	2352	0.044	579
Summer 2008				
Meadow Fescue	12.6	1559	0.030	526
Orchardgrass	18.9	2049	0.046	659
Quackgrass	10.6	1247	0.022	365
Reed Canarygrass	18.9	2201	0.035	392

[1] *Measured with a rising plate meter.*

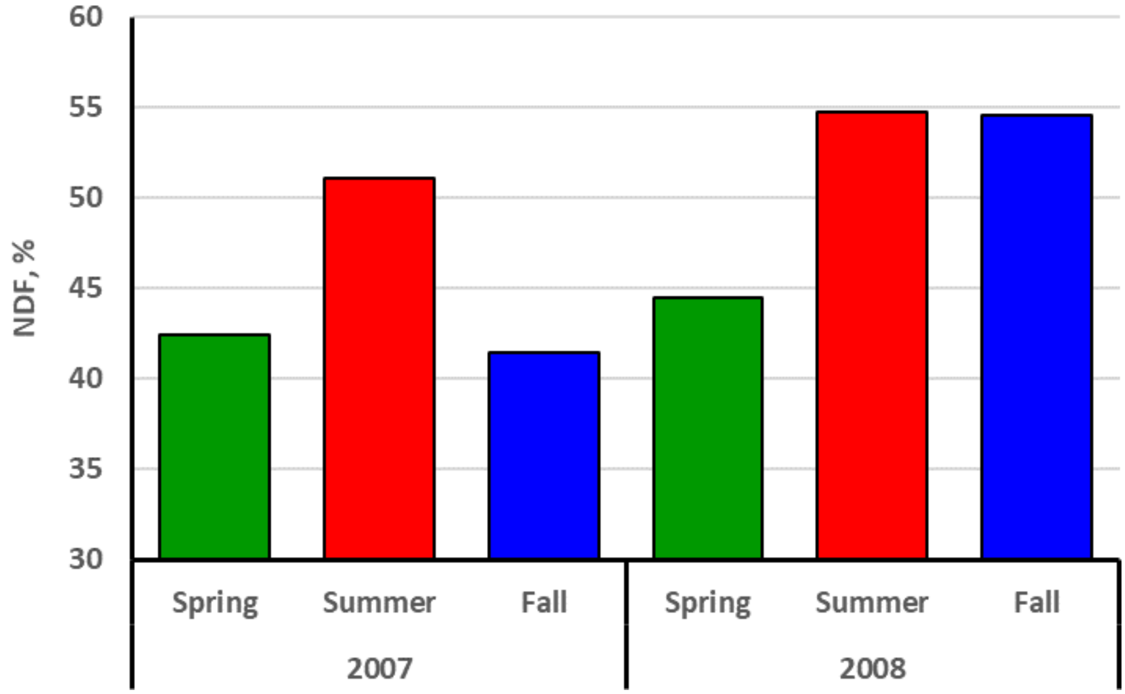

Figure 2. Seasonal evaluations of NDF for cool-season grasses (meadow fescue, orchardgrass, quackgrass, and reed canarygrass) grazed by Holstein dairy heifers at Prairie du Sac, WI, during 2007 and 2008 [adapted from Brink and Soder (2011)].

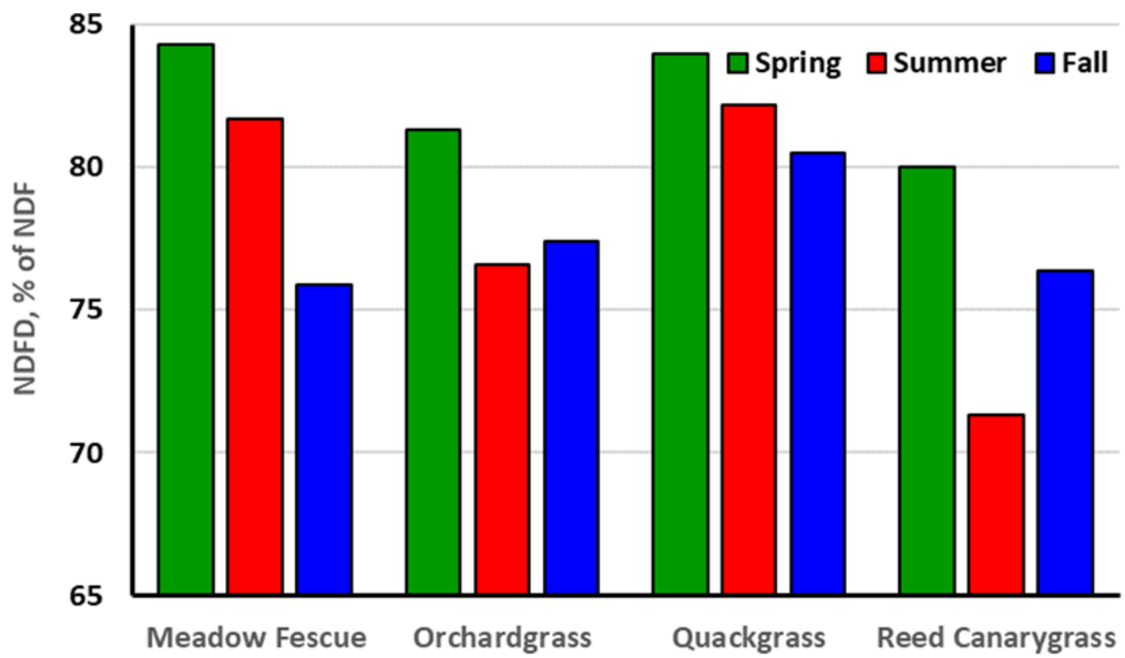

Figure 3. Seasonal evaluations of NDF digestibility (NDFD, % of NDF) for meadow fescue, orchardgrass, quackgrass, and reed canarygrass grazed by Holstein dairy heifers at Prairie du Sac, WI [adapted from Brink and Soder (2011)].

cool-season grasses, but that was not the case with the procedures used in this experiment.

The NDFD varied between forage species within seasonal evaluations (Figure 3), but effects of seasonal variation within species were also evident. Across all forage species, NDFD was 4.4 percentage units greater for growth in spring than in summer (82.4 vs. 78.0% of NDF). This could be associated with reduced lignin in forages grown under cooler temperatures. Lignin is an important component of plant cell walls that provides rigidity, functioning as a sort of the 'rebar' that helps to hold plants erect. It also is a major impediment to ruminant digestion and is generally considered indigestible. However, neither NDF nor NDFD could be directly related to forage removal by heifers. It is important to note that concentrations of NDF were low across all seasonal evaluations (41.4 to 54.7%), and the associated digestibility of NDF was extensive in all cases (71.3 to 84.3%).

This suggests that either differences in these laboratory-determined indices were not large enough to create an intake response by heifers or that the procedures used to measure forage removal by heifers were not sensitive enough to make definitive conclusions. It is also possible that lactating cows with greater nutrient demands might demonstrate a positive relationship between voluntary intake and forage nutritive value for vegetative grasses, but that remains speculative for the grazed forages in this study.

Summary

- Cool season pasture grasses used commonly throughout the north-central and northeastern United States differ in canopy layer densities and associated concentrations of NDF.
- Canopy density and NDF are affected by both seasonal and environmental conditions. These differences among species are exacerbated and most evident under good growing conditions but are less evident under dry or droughty conditions.
- Canopy densities trended toward greater representation in the 4 to 6-inch layer during fall compared to earlier assessments during the growing season. This may be the result of decreasing daylength and increased tillering.
- The greatest concentrations of NDF were typically associated with the 4 to 6-inch layer of the canopy but declined in layers positioned on more elevated vertical planes. This implies reduced intakes may be observed when animals are forced to graze lower into the pasture canopy.
- Past studies with perennial ryegrass suggest that sward height may be a determining factor affecting bite weight or voluntary intake, but that sward density becomes more important as residual sward height decreases. Within the studies reported here, primary factors potentially identified as important determinants of grazed herbage intake were leaf bulk density and stem bulk density, which had positive and negative effects, respectively.

References

Brink, G.E., M.D. Casler, and M.B. Hall. 2007. Canopy structure and neutral detergent fiber differences among temperate perennial grasses. Crop Sci. 47:2182-2189. doi:10.2135/cropsci2007.01.0045.

Brink, G.E., and K.J. Soder. 2011. Relationship between herbage intake and sward structure of grazed temperate forages. Crop Sci. 51:2289-2298. doi: 10.2135/cropsci2010.10.0600.

U.S. Dairy Forage Research Center, USDA-Agricultural Research Service
1925 Linden Drive, Madison, WI 53706 | Phone: 608-890-0050

https://www.ars.usda.gov/midwest-area/madison-wi/us-dairy-forage-research-center/

Leading the world in integrated dairy forage systems research.