Defoliation Intensity Effects on Season-Long Dry Matter Distribution and Nutritive Value of Tall Fescue

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ABSTRACT

Implementation of intensive grazing management requires knowledge about pasture growth rates and nutritive value throughout the grazing season. Such information is lacking because results from small-plot defoliation experiments generally focus on annual dry matter yields (DMYs) and season mean nutritive value. In this experiment, the influences of defoliation treatments on daily growth rate (DGR) and associated nutritive value of tall fescue (*Festuca arundinacea* Schreb.) throughout the growing season were evaluated. A 3-yr study was conducted on a Typic Kanhapludult soil near Raleigh, NC. Eight defoliation treatments (31-, 15-, 10- and 8-cm canopy heights cut to a 5-cm stubble; 31-, 15-, and 11-cm canopy heights cut to a 9-cm stubble, and an 8-cm canopy height cut to a 4-cm stubble) were evaluated in a randomized complete block design. Daily growth rates (kg ha^{-1}) were significantly ($P \leq 0.01$) altered by defoliation treatments and by years within treatments. When rainfall was near normal in both spring and late summer, tall fescue growth rates, depending on defoliation treatment, ranged from 34 to 55 kg ha^{-1} d^{-1} in May, from 7 to 18 kg ha^{-1} d^{-1} in late July, to 22 to 35 kg ha^{-1} d^{-1} in late September. In less favorable years, DGRs seldom exceeded 30 kg ha^{-1} d^{-1} in the spring or 15 to 30 kg ha^{-1} d^{-1} in the autumn. Depending on defoliation treatments, in vitro dry matter disappearance (IVDMD) ranged between 650 and 733 g kg^{-1} in the spring, 479 and 687 g kg^{-1} in midsummer, and 549 and 807 g kg^{-1} by late summer. Crude protein (CP) and detergent fiber fraction concentrations were also examined. The approach used to estimate DGR and associated nutritive value changes throughout the growing season resulted in useful data that can be applied in developing intensive grazing management practices.

Tall fescue is the major cool season, perennial forage adapted across the upper South and predominates throughout the North–South transition zone (Burns and Chamblee, 1979). This forage provides grazing in the upper South from March and into late June and from September through November when N status and rainfall are adequate. Limited growth occurs, however, during the summer stress period and during the winter months of December and February if temperatures are mild during the winter (Chamblee et al., 1995). Low temperatures generally limit all growth during January.

More effective utilization of tall fescue pastures during the spring and autumn growing periods could be achieved through intensive grazing management. This grazing strategy has both utilization (Mueller et al., 1995) and environmental advantages (Whitehead, 1995) which have economic implications. The implementation of intensive grazing management, however, requires subdivision of pastures and daily (or several-day) allocation of pasture to animals. This practice permits improved forage utilization across a short grazing period and is followed by a rest period beneficial to regrowth (Harris, 1978). Further, it provides a means of distributing animal waste across the total pasture area as opposed to concentrating nutrients (point source) around the water supply and in areas of shade (Wilkerson et al., 1989; Whitehead, 1995). To implement intensive grazing management, however, requires information on herbage mass (HM), relative DGRs, and nutritive value of tall fescue throughout the growing season.

The production potential of tall fescue, expressed as annual DMY, has been well addressed across the tall fescue transition zone (Hallock et al., 1965; Colyer et al., 1977; Matches, 1979; Smith and Calvert, 1979). Although annual yield data relative to pasture productivity are valuable, they provide little information about how the dry matter is distributed during the spring, summer, and fall growing periods. Such information is critical in the development of an intensive grazing system that mandates herbage allowance on a short-time (daily) basis as the growing season progresses. On-farm application requires continuous estimates of: (i) HM to determine land area for each allocation period, (ii) relative growth rates for the defoliation intensity used to determine subsequent reallocation intervals, and (iii) the nutritive value of the HM to assess potential daily animal responses. Results will permit meaningful estimates of paddock size and paddock number based on the stocking density required for each animal class and the animal daily performance that may be expected from a specific defoliation schedule. Such data, which has been shown estimable from small-plot clipping trials (Matches, 1968), are generally lacking in the literature for tall fescue and are not available for the Piedmont Region.

Several experiments describing the seasonal growth pattern of tall fescue have been conducted; however, these occurred in marginal soils of the Appalachian Plateau (850-m elevation). In one study, growth stages were used and growth rates determined for each harvest by dividing harvest yield by days of growth (Denison and Perry, 1990). A second study at the same location based defoliation on canopy height, and accumulative yields were fitted to the Gompertz growth equation and growth rates were determined (Belesky and Fedders, 1994). In another study at a lower elevation (≈615 m) in the Southern Appalachian Mountains, tall fescue was harvested monthly at 5- and 10-cm stubbles throughout the year and monthly DMYs presented (Dobson et al., 1978). Seasonal growth rates, however, were not re-

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Abbreviations: ADF, acid detergent fiber; CELL, cellulose; CP, crude protein; DGR, daily growth rate; DMY, dry matter yield; EDDM, estimated digestible dry matter; HEMI, hemicellulose; HM, herbage mass; IVDMD, in vitro dry matter disappearance; NDF, neutral detergent fiber.

ported. The data reported from the above studies were obtained at higher elevations in the mountains and are probably not representative of those farther east and south in the Piedmont at lower elevations (<200 m).

The objectives of this study were to determine DMY and associated nutritive value changes of tall fescue during the growing season in the Piedmont for a range of defoliation frequencies and intensities. Further, objectives were to convert discrete harvest measurements into a DGR and to present the growth rate and associated nutritive value estimates of the forage as continuous response curves that are descriptive of the growing season.

MATERIALS AND METHODS

This study was conducted at the Reedy Creek Road Field Laboratory on a Cecil clay loam (fine, kaolinitic, thermic Typic Kanhapludults) soil near Raleigh, NC. An excellent, well-established stand of 'Kentucky 31' tall fescue, representative of the majority of the pastures in the Southeast (Ball et al., 1985), was used for this study. Soil pH was maintained above 6.1 and annual February applications were made of 39 and 222 kg ha^{-1} of P and K, respectively. A seasonal total of 269 kg ha^{-1} of N was topdressed as ammonium nitrate in split applications of 113 kg ha^{-1} 15 February, 67 kg ha^{-1} 15 April, and 89 kg ha^{-1} 15 September.

Defoliation Treatments and Sampling

Eight defoliation treatments (Table 1) were randomly assigned within each of four replicates in a randomized complete block design and imposed on the same plots during this 3-yr study. Plots were 1.8 m wide and 6.1 m long with 1.5 m between replicates. The eight treatments consisted of a range of canopy heights defoliated to three different stubble heights throughout the growing season. The date of initial and final defoliation and number of defoliations varied with treatment and year (Table 1). The morphology of the tall fescue, relative to the defoliation frequencies imposed, was already established at the beginning of this experiment because the same treatments had been evaluated in a previous 3-yr study.

At harvest, a 30-cm wide strip was removed from the ends of each plot and discarded. A 51-cm wide by 5.5-m long strip was harvested with a 51-cm rotary mower. The 31-5 and 31-9 treatments (Table 1) were an exception and were cut with a 61-cm sickle-bar mower. The forage harvested with the rotary mower was directly bagged, whereas the forage cut with the sickle-bar mower was raked and placed in a cloth bag. All samples were weighed and dried in a forced-air dryer at 65°C, and DMY was calculated.

After the yield strip was removed, eight subsamples (four spaced along each edge of the harvest strip) were hand cut to the appropriate stubble from each plot, composited, quick frozen in liquid N (−370°C), and placed into a freezer (−25°C). Thereafter, samples were freeze dried, ground through a Wiley mill to pass a 1-mm screen, and returned to the freezer until analyzed. All samples were analyzed for IVDMD (Burns and Cope, 1974), neutral detergent fiber (NDF), acid detergent fiber (ADF), and permanganate lignin (Goering and Van Soest, 1970). Cellulose (CELL) was determined by subtracting lignin plus ash from ADF. Hemicellulose (HEMI) was determined by subtracting ADF from NDF. Samples from the 10-5 and 15-5 and from the 11-9 and 31-9 treatments (Table 1) were further analyzed for total N (Association of Official Analytical Chemists, 1990), multiplied by 6.25, and expressed as CP, and for water soluble carbohydrates (Deriaz, 1961).

Changes in Daily Growth Rate and Nutritive Value

Daily growth rate was determined for each treatment each year by first plotting the accumulated DMY during the season on the *y*-axis against each discrete harvest date on the *x*-axis. Initiation of growth was assumed to be 10 February each year. A smooth spline function was fitted to the accumulated DMY values and used to compute interpolated daily accumulated DMY values. The difference between successive interpolated or predicted DMY values were interpreted as estimated derivatives of growth rate with respect to time. This was done separately for each treatment, year, and replicate combination (i.e., for each plot). Further statistical analyses were performed on these estimated DGRs during the growing season when all treatments in all years were comparable. The additional data collected in late October and November for some treatments were included in the figures to show autumn trends. Means and LSDs for year and treatment were computed at each day, and the results plotted against the dates. Note that the LSDs are point-wise calculations, that is, they are calculated for individual days and consequently, valid only at the specific time points where they were computed. Whereas the LSDs for adjacent days are not independent, the changes in LSDs across time provide a valid picture of changes in estimates of mean growth rates across time. Changes in daily concentrations (g kg^{-1}) of IVDMD, CP, NDF, ADF, HEMI, CELL, and lignin were determined in the same way as DGRs, and the replotted data fit with a splinned polynomial to describe the growing season.

Table 1. Treatment designation, description, initial and final harvest dates, and total number of harvests for each treatment each year.

Defoliation treatments			Harvest dates								
Actual height		Rounded designation†	Initial date			Final date			Total harvests		
Canopy	Stubble		Yr. 1	Yr. 2	Yr. 3	Yr. 1	Yr. 2	Yr. 3	Yr. 1	Yr. 2	Yr. 3
cm											
7.6	3.8	8-4	9/4	6/4	31/3	10/10	5/11	5/11	10	10	16
7.6	5.1	8-5	9/4	6/4	31/3	10/10	13/11	18/11	13	14	17
10.1	5.1	10-5	9/4	6/4	31/3	10/10	5/11	5/11	11	10	15
15.2	5.1	15-5	21/4	23/4	9/4	17/10	5/11	18/11	6	5	8
30.5	5.1	31-5	24/4	5/5	3/5	3/10	1/12	5/11	4	3	4
11.4	8.9	11-9	9/4	6/4	31/3	17/10	13/11	18/11	14	15	22
15.2	8.9	15-9	9/2	15/4	9/4	17/10	5/11	5/11	13	7	12
30.5	8.9	31-9	24/4	5/5	3/5	3/10	1/12	5/11	4	3	5

† For simplicity of discussion, the actual canopy and stubble heights have been rounded and designated with canopy height first followed by stubble height. For example, a 7.6-cm canopy height cut to a 3.8-cm stubble has been designated as 8-4. This indicates that each time the canopy reached 8 cm during the growing season it was cut to a 4-cm stubble height.

Table 2. Set of six meaningful comparisons included in the analyses of variance for the annual yields of tall fescue.

Comparison no.	Defoliation Intensity
	Stubble height
1	4 cm vs. 5 cm (8-4 vs. 8-5)
2	5 cm vs. 9 cm (10-5, 15-5, 31-5 vs. 11-9, 15-9, 31-9)
	Canopy height at 5-cm stubble
3	30-5 vs. (10-5, 15-5)
4	10-5 vs. 15-5
	Canopy height at 9-cm stubble
5	31-9 vs. (11-9, 15-9)
6	11-9 vs. 15-9

Annual Yields

Total DMY for the season was determined by totaling the DMY from each harvest within each treatment. Season CP yields and total estimated digestible dry matter (EDDM) yields were determined by multiplying DMY by the appropriate CP or IVDMD concentration, respectively, for each harvest and totaling all harvests for each year within a treatment.

Statistical Analyses

A LSD using a pooled error was determined for DGRs and daily concentrations of IVDMD and CP to make comparisons among treatments within years and is presented at 10-d intervals throughout the growing season. An LSD was determined for NDF and its fiber constituents to make comparisons among treatments averaged across all 3 yr. An LSD was also determined to make among-year comparisons within the 10-5, 15-5, and 31-5 defoliation treatments for 10-d intervals throughout the growing season.

The annual yields of DM, CP, and EDDM were statistically analyzed in a combined analysis for a randomized complete block design with year treated as a stripped effect (SAS Institute, 1995). All yield data showed a significant year × treatment interaction and were reanalyzed by year and presented by year. A set of six meaningful comparisons were included in the analyses of variance for the annual yields, as noted in Table 2.

Comparisons 1 and 2 evaluated different defoliation intensities (stubble heights), Comparisons 3 and 4 evaluated different defoliation frequencies at a 5-cm stubble, and Comparisons 5 and 6 evaluated different defoliation frequencies at a 9-cm stubble. A minimum significant difference from the Waller-Duncan K-ratio *t*-test (K = 100) (SAS Institute, 1995) also was included for other comparisons of interest.

RESULTS AND DISCUSSION

Temperature in the spring and rainfall distribution, hence soil moisture status, during the growing season are important influences on when growth begins in the spring and the rate at which forage accumulates from one harvest to the next. Year 1 showed above average rainfall in March with some deficiencies in April and May, but with above average rainfall in June, August, and September (Table 3). Mean air temperatures were below average in all months except July, which was near average.

In Year 2, below average rainfall fell in March through June and in August with the deficit in June being most severe. September was dry and October wetter than average. The spring and summer were cooler than average, but the autumn warmer than average (Table 3). The autumn conditions are reflected in the later final harvest dates compared with Year 1 (Table 1). Year 3 began with above average rainfall in February and March, which continued with alternating below and above average rainfall in April through September. October was extremely wet. Mean air temperatures were below average in spring and summer, whereas autumn temperatures were above average. These weather conditions are reflected in the early initial and late final harvest dates noted for Year 3 compared with Years 1 and 2 (Table 1). In general, departures in rainfall during each year of the 3-yr study were not very extreme nor prolonged, but were of sufficient scope to alter forage production.

Seasonal Responses

Annual total DMY and associated estimates of nutritive value of tall fescue from defoliation treatments, presented later, are informative regarding the overall forage productivity and its potential as a livestock feed. Data as such, however, are essentially useless for developing intensive grazing systems. This requires estimates of HM, forage growth rates, and nutritive value of the harvested forage across short-increments of time (1 wk or less) throughout the entire growing season. Such data permit estimates of paddock number, paddock size relative to necessary stocking density, and the daily animal performance expected from a specific defoliation schedule.

Table 3. Climatological data recorded ~5 km from the experimental site.†

	30-year mean		Year 1 departures		Year 2 departures		Year 3 departures	
Month	Rainfall	Temp.	Rainfall	Temp.	Rainfall	Temp.	Rainfall	Temp.
	mm	°C	mm	°C	mm	°C	mm	°C
January	84	5.3	−42	−2.3	−24	−4.8	2	−2.6
February	93	6.2	9	−1.1	6	−2.3	15	−0.5
March	92	10.2	15	−3.2	−42	−1.8	9	−2.5
April	83	15.2	−52	−0.3	−11	0.1	−23	−1.6
May	95	18.0	−17	−0.8	−4	−0.9	29	−1.8
June	105	24.1	28	−0.2	−71	−1.3	−23	0.2
July	136	25.7	−27	0.1	4	−1.0	−23	−0.7
August	133	25.1	28	−1.7	−18	−0.9	27	−0.9
September	93	22.1	59	−2.0	−66	1.2	−23	0.5
October	73	16.0	−15	−1.1	44	0.3	121	2.4
November	63	10.4	−44	−2.1	−29	−0.4	−24	−0.8
December	80	6.0	7	−2.4	−11	0.5	−33	0.6

† Data recorded at the Raleigh-Durham International Airport by the National Oceanic and Atmospheric Administration.

This section presents defoliation influences on tall fescue mean DGR and the associated nutritive value of the forage throughout the growing season (Fig. 1–8). Defoliation or year main effects, as appropriate, can be examined during the growing season at 10-d intervals by using the appropriate LSD given in the figures. Consider Fig. 1 for example. The LSDs for every tenth day are given as bars, as well as numerically, at the top of the figure. The length of the bars indicate that the estimates of the growth rate curves are subject to much greater variability in May–June than in late August–early September. In Year 1, the evidence for differences among treatments is weak, except possibly near the end of the season. Alternatively, in Year 2 there is fairly strong evidence of treatment differences in June and again in late July and early August. Strong evidence of treatment differences occurs in the first half of Year 3, but not in the second half. Although only general trends are discussed below for each variable measured, many specific comparisons among defoliation treatments can be made and are left to the interest of the reader.

Daily Growth Rate

Daily growth rate of tall fescue during the growing season differed among defoliation treatments (Fig. 1) and among years (Fig. 2) within defoliation treatment, but the year × treatment interaction was not significant ($P \leq 0.05$). The more typical seasonal DGR of tall fescue is high during the spring, followed by a midsummer decline with renewed growth occurring in the autumn (Chamblee et al., 1995). This growth distribution is represented in Year 3 (Fig. 1). In the third year, the 31-9 or 31-5 defoliation treatments showed highest growth rates into midsummer with little difference noted thereafter among defoliation treatments until late September. In Year 1, except in May, few differences in DGR were noted among defoliation treatments (Fig. 1), while in Year 2 differences during the growing season were large. In Year 2, the less intensive defoliations (31-9 or 31-5) showed trends that were different from the intermediate defoliation (15-9 or 15-5), and both showed different trends than noted for the intensive defoliations (11-9, 10-5, 8-5, or 8-4). The low growth

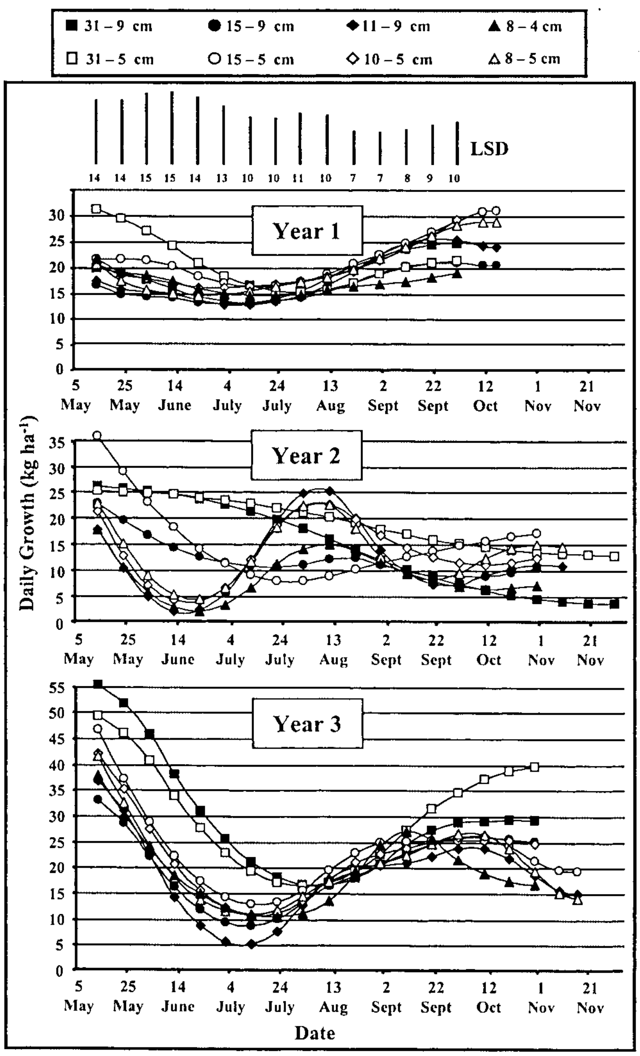

Fig. 1. Daily growth rate changes of tall fescue by year throughout the growing season from eight defoliation intensities. The LSD ($P \leq 0.05$) applies to all years.

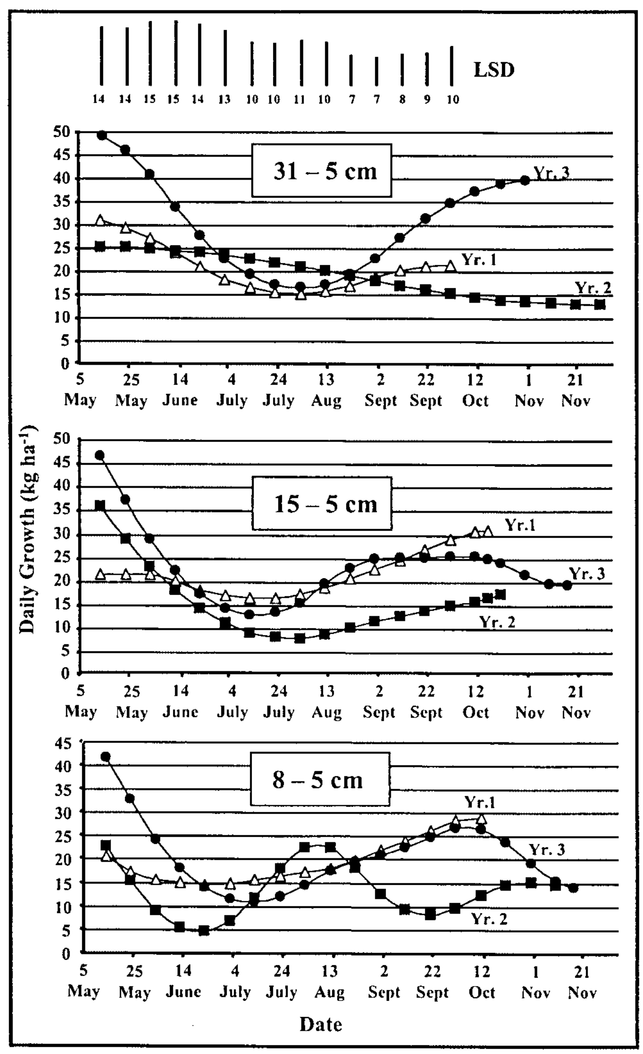

Fig. 2. Daily growth rate changes of tall fescue throughout the growing season among years within the 5-cm stubble defoliation series. The LSD ($P \leq 0.05$) applies to all defoliation treatments.

rate noted in the spring of Year 2, especially for the intensive defoliation treatments, followed by increased growth in July and August is attributed, in part, to below normal rainfall in the spring, with more favorable rainfall in July and early August (Table 3). Daily growth rate of tall fescue is highly influenced by rainfall and temperature.

Mean DGR during the growing season differed among years within defoliation treatments (Fig. 2). Because the 9-cm and 5-cm defoliation series showed similar year-to-year differences, for simplicity, only the 5-cm defoliation treatments are shown. Large year-to-year differences are noted with Year 3 generally having the higher DGR during the growing season than either Years 1 or 2. These large year-to-year seasonal differences in DGR must be given consideration in developing season-long intensive grazing management systems to avoid overstocking or in planning an adequate supply of conserved forage for the stocking rate desired.

Nutritive Value

Defoliation treatments altered the concentrations of all of the nutritive value estimates determined with year effects being significant only for IVDMD and CP. The defoliation treatment × year interaction was not significant.

In Vitro Dry Matter Disappearance, Crude Protein, and Water Soluble Carbohydrates

Generally, IVDMD was lowest during the growing season for the least frequently defoliated treatments (Fig. 3: Treatments 31-9 and 31-5). On the other hand, forage from treatments more frequently defoliated (≤15

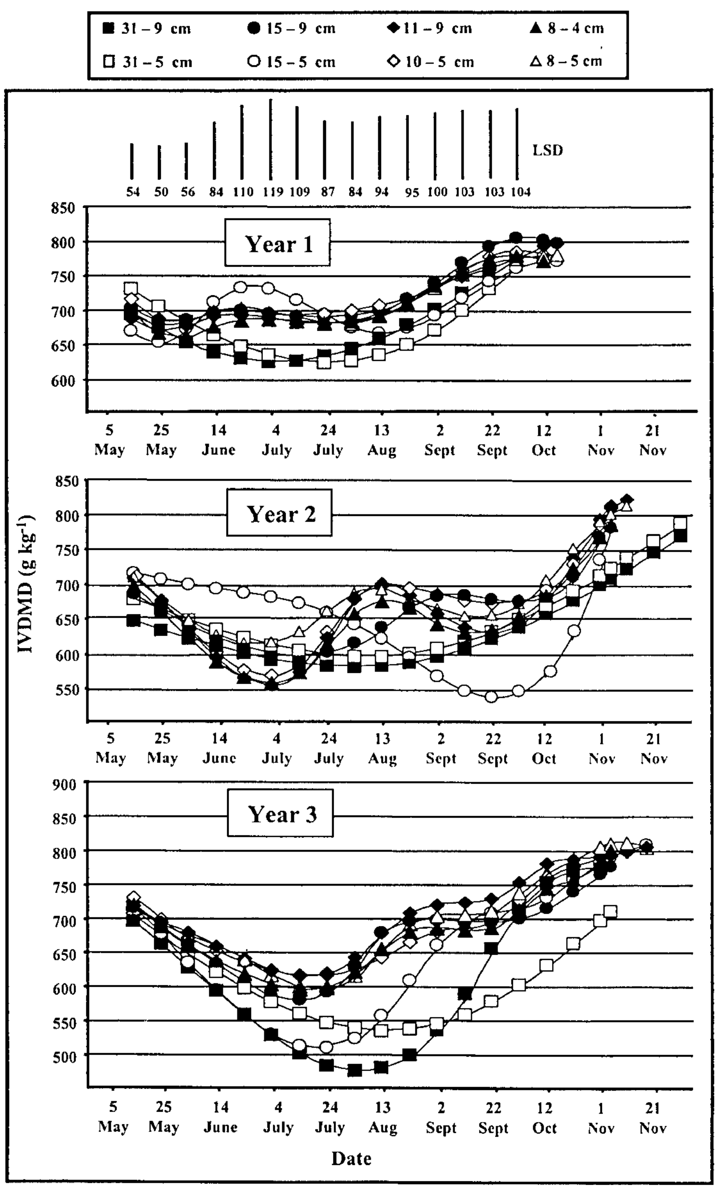

Fig. 3. Changes in in vitro dry matter disappearance (IVDMD) of tall fescue by year throughout the growing season from eight defoliation intensities. The LSD ($P \leq 0.05$) applies to all years.

cm) were higher in IVDMD during the growing season and generally similar in concentrations. Year differences were highly variable as noted for the 5-cm defoliation series (Fig. 4). For example, differences in IVDMD from the 15-5 defoliation treatment on 4 July ranged from ≈530 g kg^{-1} in Year 3 to ≈740 g kg^{-1} in Year 1.

Crude protein concentrations from selected defoliation treatments (31-9, 11-9, 15-5, and 10-5) were similar during the growing season in Year 1 (Fig. 5) but were numerically lower for the 31-9 defoliation treatment in Years 2 and 3. Higher CP concentrations in the forage occurred during the growing season from the more frequent defoliation treatments in Year 3. The year effect on CP concentrations during the growing season was large as shown for selected treatments (Fig. 6). Defoliation treatments that resulted in CP concentration of <150 g kg^{-1} during the growing season may limit the performance of young stock (calves weighing from 136 to 227 kg) which obtain their major supply of daily nutrients from pasture (National Research Council, 1996). In some years (Fig. 6), for example, CP concentrations on some treatments fell below 150 g kg^{-1} in the summer to as low as ≈110 g kg^{-1}.

Water soluble carbohydrates were altered by defoliation treatments as noted from the selected treatments analyzed (Fig. 7: Treatments 31-9, 11-9, 15-5, and 10-5). Differences occurred beginning 4 July and existed through early September. The 31-9 defoliation resulted in consistent lower WSC concentration, averaging only 80 g kg^{-1} in July and increased slowly to >95 g kg^{-1} by early September. The more frequent defoliation increased WSC from ≈90 g kg^{-1} to 125 g kg^{-1} or higher during the same period. Very rapid increases in WSC were noted in the 11-9 and 15-5 defoliation treatments

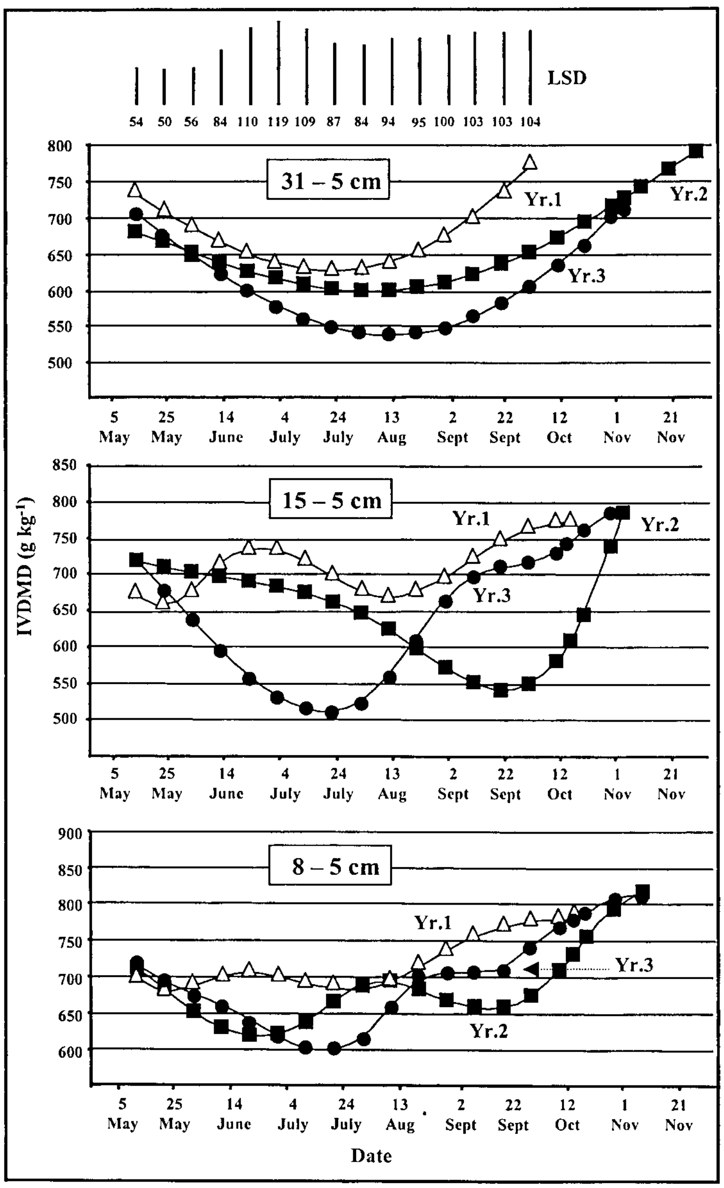

Fig. 4. Changes in vitro dry matter disappearance (IVDMD) of tall fescue throughout the growing season among years within the 5-cm stubble defoliation series. The LSD ($P \leq 0.05$) applies to all defoliation treatments.

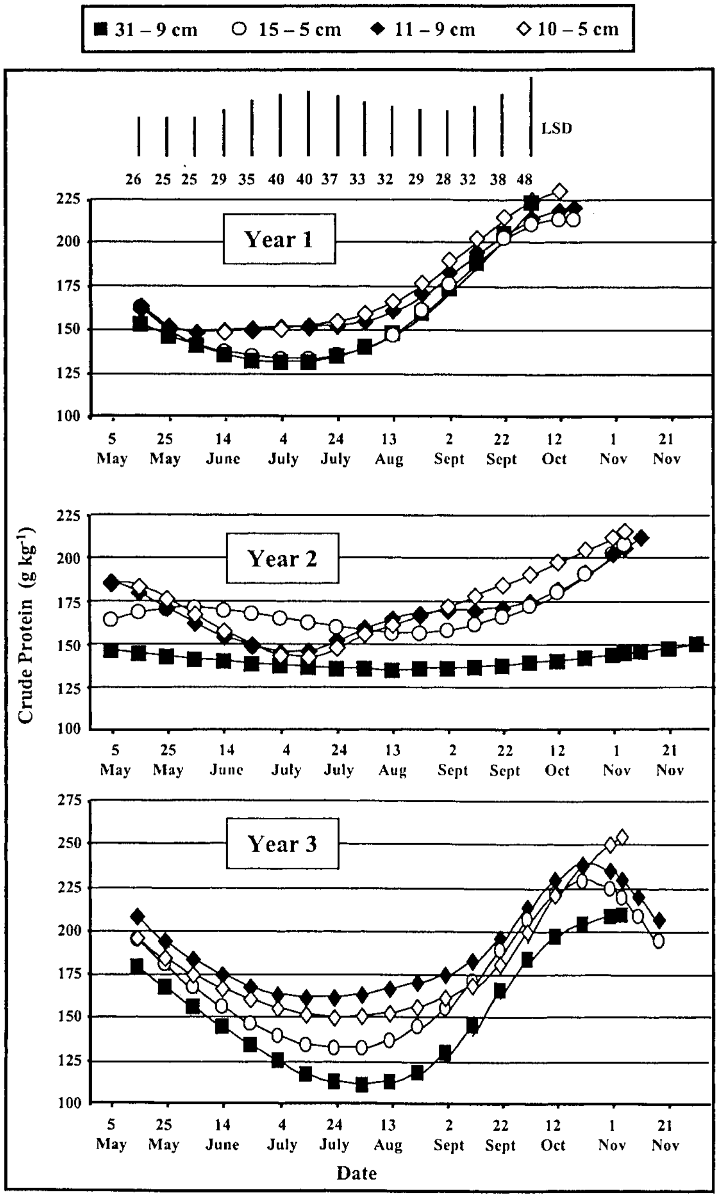

Fig. 5. Changes in crude protein of tall fescue by year throughout the growing season from four selected defoliation intensities. The LSD ($P \leq 0.05$) applies to all years.

by early November. This trend of increased WSC is generally reflected in increased IVDMD during July to September and on into November.

Neutral Detergent Fiber and Constituent Fractions

Defoliation treatments altered NDF concentrations of the forage as well as constituent fiber concentrations (Fig. 7 and 8). In general, the least intensive defoliation treatments (31-9, 31-5) resulted in forage with highest NDF and constituent fiber concentrations during the growing season while the more intensive defoliation treatments produced forage with lower concentrations. The noted exception was for lignin (Fig. 8) in which the 8-4 defoliation treatment resulted in forage with large increases in lignin in May through July. The cause of this response is not clear, but may be associated with higher lignin concentrations present in basal stems. Little difference was noted among the four more intensive defoliation treatments (11-9, 10-5, 8-5, and 8-4) during the growing season in NDF and associated fiber concentrations of the forage.

Application of Seasonal Data

The changes in tall fescue growth rate, both during the grazing season and among defoliation treatments, indicate why variable stocking is important if animals are depending on tall fescue pasture as the sole source of nutrient intake. In developing flexible grazing systems (Blaser et al., 1976), estimates of pasture growth rates and nutritive value, as presented here, are essential in properly allocating forage for effective utilization and to allocate other feed sources in obtaining the animal response desired (Burns, 1982). The data indicate that

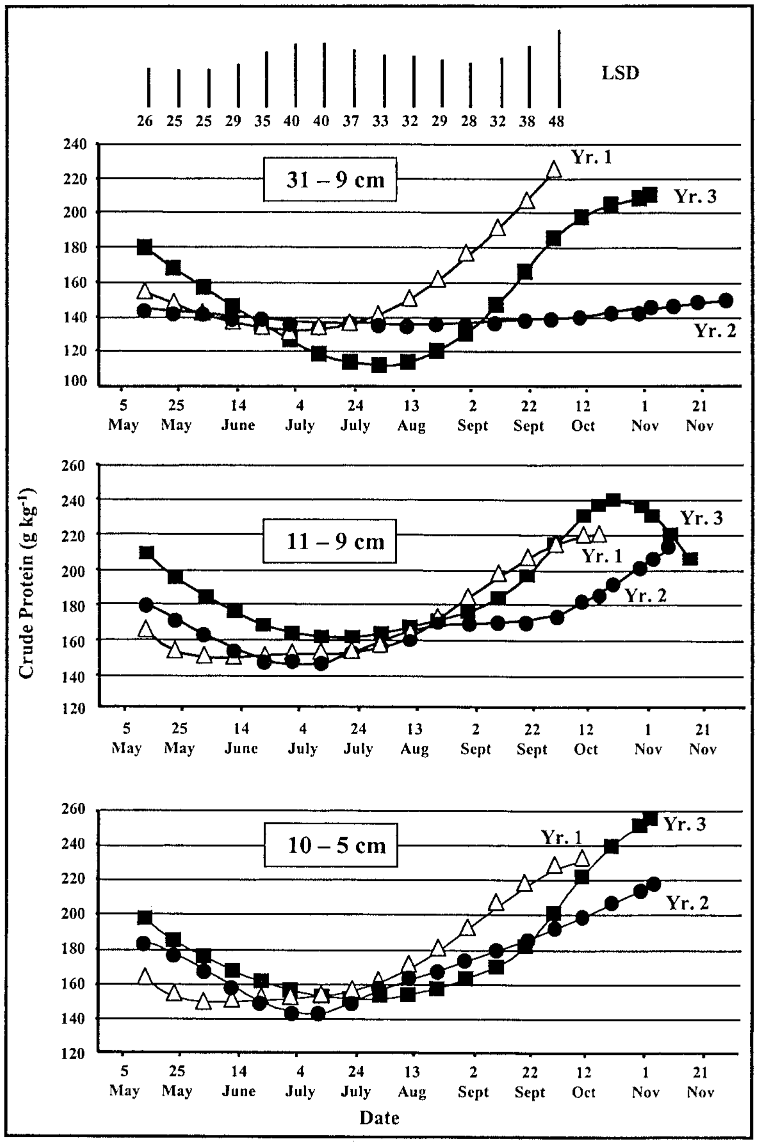

Fig. 6. Changes in crude protein of tall fescue throughout the growing season among years within the three selected defoliation intensities. The LSD ($P \leq 0.05$) applies to all defoliation treatments.

if animal numbers are to remain near constant during the grazing season, that paddock size or rotation interval, or both, must be adjusted from spring to summer to fall, depending on the animal response targeted by the manager.

ANNUAL PRODUCTION

Dry Matter Yield

The defoliation treatments resulted in different total DMY among years. Year 3 was the most productive, averaging 6655 kg ha^{-1}, compared with <4700 kg ha^{-1} in Year 1 (Table 4). This was attributed, in part, to above average rainfall in August and September of Year 3 (Table 3), which stimulated late summer production. Stubble height influenced annual DMY in all years. Harvesting to a 5-cm compared with a 9-cm stubble (C2, Table 4) resulted in higher DMY across the range of canopy heights evaluated in all 3 yr (Table 4). The mean difference, 6030 vs. 4975 kg ha^{-1}, represents a 21% increase in DMY from the 5-cm stubble and similar to the 26% increase reported by Dobson et al. (1978) when harvesting tall fescue to 5-cm vs. a 10-cm stubble (9100 vs. 7230 kg ha^{-1}). A comparison of two of the more intensive defoliation managements (15-5 vs. 15-9) showed a 37% increase (5800 vs. 4220 kg ha^{-1}) in DMY in favor of the 5-cm stubble height (Table 4). This trend was also noted at the next lower canopy height of 10 to 11 cm with the 10-5 defoliation treatment producing 21% more DMY compared with the 11-9 defoliation treatment (5045 vs. 4175 kg ha^{-1}). Tall fescue growth responded favorably to close defoliation, but harvesting too intensively was detrimental to production as defoliation from the 8-4 vs. the 8-5 treatment reduced DMY 12% (4460 vs. 4990 kg ha^{-1}). This difference (C1, Table 4), was significant in Years 1, 2 ($P \leq 0.01$), and 3 (P = 0.13). Such close continuous defoliation below 5 cm was not advantageous, but DMYs were as much if not more

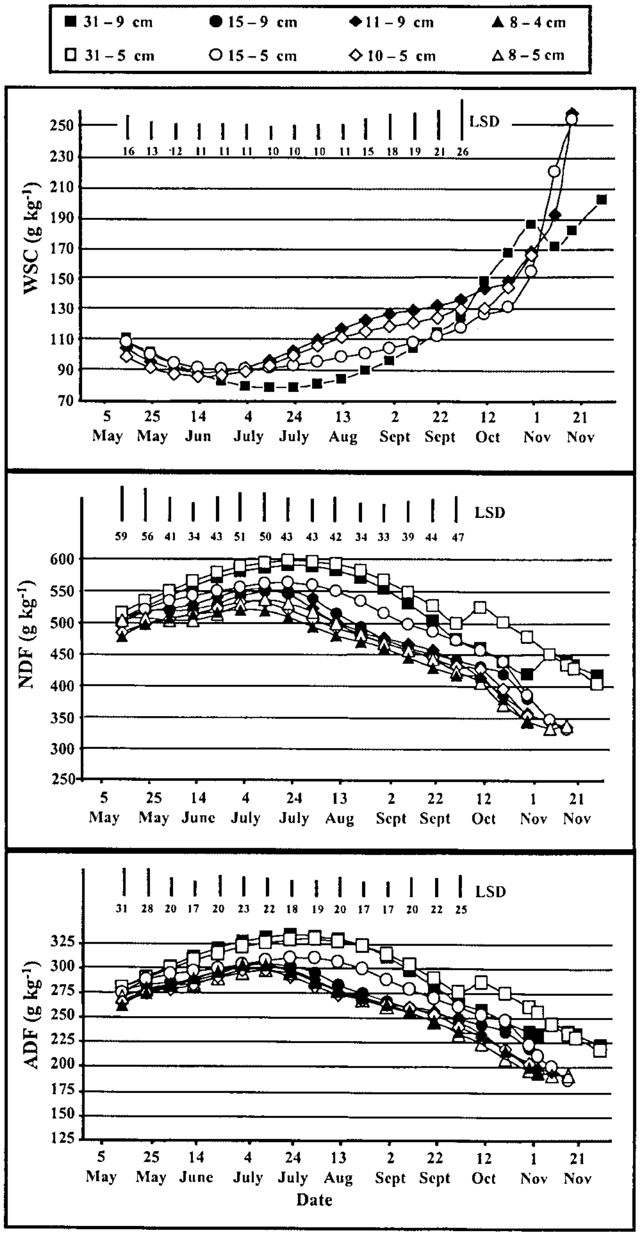

Fig. 7. Changes in water soluble carbohydrates (WSC), neutral detergent fiber (NDF), and constituent acid detergent fiber (ADF), of tall fescue throughout the growing season (mean 3 yr) from multiple defoliation intensities (LSD; $P \leq 0.05$).

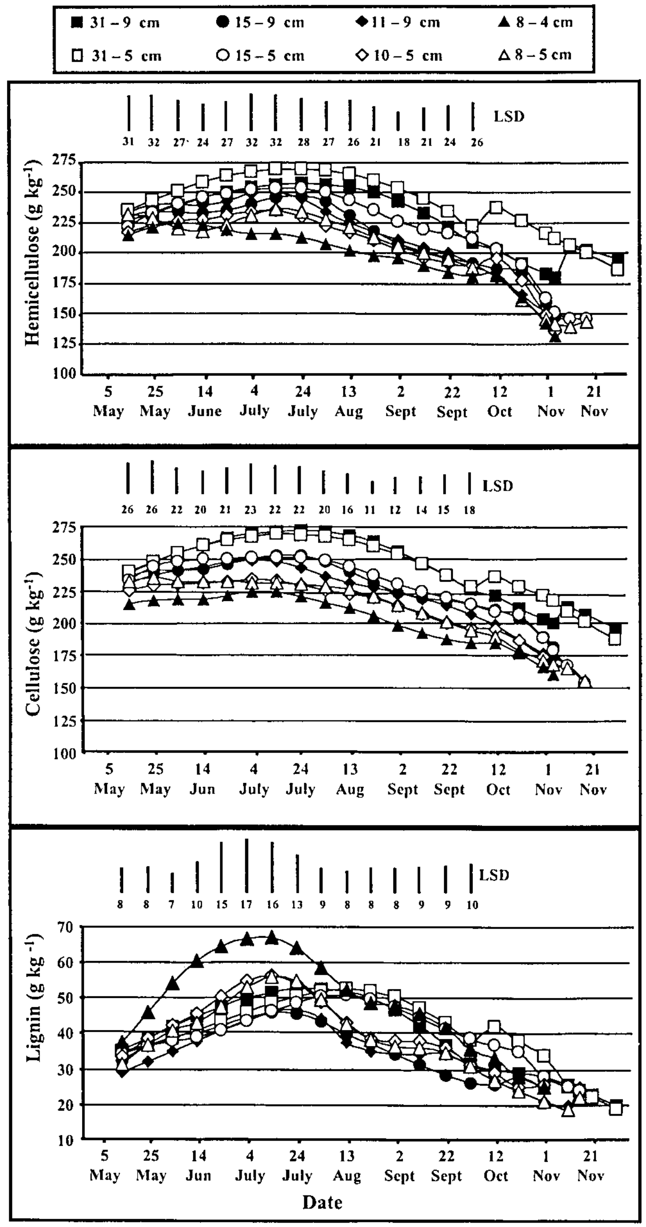

Fig. 8. Changes in hemicellulose, cellulose, and lignin of tall fescue throughout the growing season (mean 3 yr) from multiple defoliation intensities (LSD; $P \leq 0.05$).

than obtained from the more intensive defoliations at the 9-cm stubble.

Within the 5-cm stubble (C3, Table 4) or within the 9-cm stubble (C5) treatments, harvesting when forage growth reached 31 cm resulted in higher DMY compared with harvesting when forage growth reached either 10- or 11-cm or 15-cm. This is consistent with the relationship between leaf area index and net photosynthesis (Pearce et al., 1965). Within the 5-cm stubble, defoliation from a 15-cm canopy resulted in greater DMY than defoliation from a 10-cm canopy, while defoliation from an 8-cm canopy resulted in lowest DMY (C7, Table 4). This did not occur within the 9-cm stubble, as DMY were similar when defoliation was from a 15- or 11-cm canopy height.

Digestible Dry Matter Yield

The annual mean (weighted for harvest) IVDMD for the 3 yr ranged from 679 g kg^{-1} from Treatment 8 (31-9) to 743 g kg^{-1} from Treatment 3 (10-5), with an average of 721 g kg^{-1} (data not shown). With this small range in IVDMD among defoliation treatments, the DMY component dominated the EDDM yields obtained (Table 4). Consequently, the pattern of significance was nearly identical to DMY (Table 4) and the defoliation height and stubble height effects were the same as noted above for DMY. In general, the tradeoff between quantity (yield) and nutritive value (IVDMD) was evident with the more lax defoliations (31-5 and 31-9) resulting in highest EDDM yield due to the DMY component,

Table 4. Annual dry matter and digestible dry matter yields of tall fescue from eight defoliation treatments and N yields from four defoliation treatments (oven-dry basis).

		Dry matter‡			Digestible dry matter§			N¶		
	Treatment†	Year 1	Year 2	Year 3	Year 1	Year 2	Year 3	Year 1	Year 2	Year 3
no.	cm	kg ha^{-1}								
1	8-4	4165	3155	6050	3060	2300	4455	–	–	
2	8-5	4585	4000	6385	3410	2950	4750	–	–	–
3	10-5	4705	3880	6560	3550	2830	4880	148	110	209
4	15-5	5350	4710	7330	3595	3255	5210	160	123	228
5	31-5	5690	7070	8950	4120	4820	6030	–	–	–
6	11-9	4060	3555	4910	3010	2610	3650	125	98	159
7	15-9	3830	3770	5060	2890	2670	3635	–	–	–
8	31-9	5105	6475	8000	3690	4200	5325	138	149	215
Meaningful comparisons (Probability level)										
C1 (1 vs. 2)		<0.01	<0.01	0.13	<0.01	<0.01	0.05	–	–	–
C2 (3, 4, 5, vs. 6, 7, 8)		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.19	0.03
C3 (5 vs. 3, 4)		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	–	–	–
C4 (3 vs. 4)		<0.01	<0.01	<0.01	<0.01	0.03	0.03	0.04	0.17	0.32
C5 (8 vs. 6, 7)		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	0.02
C6 (6 vs. 7)		0.09	0.43	0.49	0.26	0.75	0.93	–	–	–
C7 (2 vs. 3, 4, 5)		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	–	–	–
MSD#		245	495	405	205	350	265	11	20	44
Mean		4685	4575	6655	3415	3205	4740	143	120	203
CV (%)		3.9	8.2	4.6	4.4	8.2	4.2	3.8	8.1	10.4

† Treatment designations represent plant growth defoliated to a specific stubble; for example, 8-4 designates that each time tall fescue growth attained 8 cm it was cut back to 4-cm stubble.
‡ Each value is the mean of four replicates totaled for 3 to 22 harvests, depending on year and treatment.
§ Each value is the mean of four replicates determined by multiplying the in vitro dry matter disappearance and dry matter yield at each harvest and summed for 3 to 22 harvests, depending on treatment and year.
¶ Each value is the mean of three replicates determined by multiplying total N and dry matter yield at each harvest and summed for 3 to 22 harvests, depending on treatment and year.
# MSD = minimum significant difference based on the Waller-Duncan K-ratio (K = 100) *t*-test.

and the more intensive defoliations giving forage of higher IVDMD but much lower DMY.

Nitrogen Yield

Nitrogen removal in the forage was estimated for four of the eight treatments and averaged 143 kg ha^{-1} in Year 1, 120 kg ha^{-1} in Year 2, and 203 kg ha^{-1} in Year 3 (Table 4). Defoliation at 15-5 vs. 10-5 resulted in greater N removal in the forage only in Year 1 (C4, Table 4). At the most lax defoliation (31-9), N removal was consistently greater than the more intensive defoliation within the same stubble height (11-9) (C5, Table 4). Comparing N removal, forage with similar canopy heights but different stubble heights (10-5 vs. 11-9) showed greater removal from the 10-5 defoliation in Years 1 and 3 (C2, Table 4). These differences were mainly associated with differences in DMY as changes in N concentrations (data not shown) were not large, averaging (weighted for harvest) for the 3 yr 192, 183, 193, and 162 g kg^{-1} for the 10-5, 15-5, 11-9, and 31-9 defoliations, respectively. Although total N recovery was not determined in this study, it is of interest to note that of the 269 kg ha^{-1} N applied, the 15-5 defoliation, of those evaluated, gave the highest apparent N recovery, averaging 59.5, 45.8, and 84.8% for Years 1, 2, and 3, respectively. The high apparent recovery noted in Year 3 is associated with the most favorable growing conditions during the study (Table 3).

SUMMARY

Defoliation intensity significantly ($P < 0.01$) altered annual dry matter production and associated nutritive value of tall fescue. Generally, the less intensive defoliation treatments resulted in greater annual DMYs and reduced nutritive value estimates than did the more intense treatments. A more pressing issue when developing intensive grazing management systems, however, is how defoliation intensity alters dry matter production and associated nutritive value during the total grazing period. The approach used in this study of expressing discrete harvest and associated nutritive value estimates as daily-response changes throughout the growing season provided estimates of each variable analyzed that can be used in structuring grazing systems. This process requires frequent estimates of pasture growth rate and nutritive value. Altering forage growth rate and nutritive value during critical stress periods during the summer through defoliation intensity may be of more economic advantage than simply generating greater annual forage production. This study provides comparisons among eight defoliation treatments at 10-d intervals during the growing season and will assist the meaningful structuring of intensive grazing management systems.

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