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Winter Tall Fescue Yield and Quality with Accumulation Periods and Nitrogen Rates

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Winter Tall Fescue Yield and Quality with Different Accumulation Periods and N Rates[1]

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ABSTRACT

Tall fescue (*Festuca arundinacea* shreb.) is used extensively for pasture, hay, and accumulated after midsummer (stockpiled) for winter grazing. The stockpiled canopies are suitable for winter grazing because of high yield, and the erect leaves remain green after several freezes, causing rather high protein contents and feeding values. More information is needed on yield and quality; hence, this investigation was planned to measure the quality [crude protein (CP) and total nonstructural carbohydrates (TNC)] and yield of stockpiled growth as influenced by June, July, August, and September dates of applying N and stockpiling the growth. Winter influence on the quality and yield of the stockpiled forage was also measured by sampling the accumulated canopies in early (December) and late winter (February). Summer regrowth yields were also measured and the soil is classified as Groseclose loam (Typic Hapludults, clayey mixed, mesic).

As the age of the tall fescue stockpiled canopies harvested in December decreased from the June to September, stockpiling dates (SD), the dry matter (DM) yields decreased from 3,920 to 840 kg/ha, TNC increased from 15.6 to 23.0%, CP increased from 9.4 to 11.3%, and the chlorophyl index (CI) increased from 32 to 45. When N application was delayed from the June to the September dates, the DM decreased from 3,990 to 3,350 kg/ha, TNC increased from 17.4 to 23.8%, CP increased from 9.0 to 13.2%, and CI increased from 31 to 61. However, a stockpiling date × N interaction occurred because the stockpiled yields tended to decrease with delayed N applications for the June and July SD but increased for the August and September SD. Total DM yields (stockpiled plus summer growth) were highest for the earliest N applications. Dates of starting stockpiling affected the distribution of grazable forage with the highest summer production being 2,880 kg/ha with the September SD. The early June SD does not provide summer pasture, but would reduce the area needed for winter grazing because of the highest yield.

The quality and yields of stockpiled tall fescue declined as the winter season advanced. DM, CP, and TNC values of stockpiled tall fescue in February were lower than in December, but highly, and positively correlated to the December values: DM ($r = 0.95$), TNC% ($r = 0.88$), TNC yield ($r = 0.92$), CP% ($r = 0.99$), CP yield ($r = 0.95$), and CI ($r = 0.89$). As compared to no N, and N fertilized forage lost more yield and quality in absolute terms, but continued to be higher in DM and quality in February due to high initial levels.

Additional index words: *Festuca arundinacea* Schreb., Crude protein, Total nonstructural carbohydrates, Yield, Quality, Chlorophyl index, Stockpiling.

IN much of the USA, deferred winter grazing of summer-fall grown tall fescue provides a relatively inexpensive forage for livestock. Performance of cattle grazing tall fescue (*Festuca arundinacea* Schreb.) pasture during summer is generally not as good as for bluegrass (*Poa pratensis* L.), or orchardgrass (*Dactylis glomerata* L.) pastures. However, good livestock performance has occurred with winter grazing of tall fescue canopies. When using tall fescue pasture systems for wintering cows in Virginia (4) and Ohio (14), winter weight changes and calf birth weights were similar to conventional hay feed systems. Brown et al. (5), reported an increase in in vivo dry matter digestion as tall fescue grew from August into October and then a decrease in late November. Bryan et al. (7), and Taylor and Templeton (13) likewise noted increases in dry matter digestibility or nutritive value index for fescue during the late summer to fall season. However, these investigations were confounded by changing ages of the grass and fall climatic conditions as harvesting dates varied.

Our research provides information on the influence of various lengths of accumulating (stockpiling) tall fescue canopies and dates and rates of N on yield and quality, when all stockpiled growth were evaluated under a given climatic environment in December and again in February. Two winter sampling dates provide data on yield and quality declines during winter. Yield distributions of summer regrowth were also measured.

MATERIALS AND METHODS

Established stands of 'Kentucky 31' tall fescue grown on a Groseclose silt loam (clayey, mixed, mesic, Typic Hapludult) near Blacksburg were fertilized with 60 kg/ha of P in spring of 1975 and 1976. Tall fescue canopies cut at different summer dates, were accumulated for December and February harvesting to simulate winter grazing. Canopy accumulation (stockpiling) began on 3 June, 9 July, 5 August, and 15 September in 1975 and 14 June, 15 July, 17 August and 15 September in 1976. Nitrogen at 0 and 112 kg N/ha at these four monthly dates was used with each of the four stockpiling dates in a 4 × 5 factorial split plot design with three replications. The main plots were stockpiling dates and N rates and dates were subplots. The spring growths for all treatments were harvested on the June date each year. At each stockpiling date after June, the main plots were cut at ascertain summer production. Winter yields of 1975 stockpiled fescue were taken on 13 December and 13 February 1976. The 1976 stockpiled fescue was harvested 1 December. All harvests were cut to a 3.8 cm stubble height.

Analyses were made for total nonstructural carbohydrates (TNC) using Wolf and Ellmore's (15) method and CP was determined by macro-Kjeldahl (1). A chlorophyl index (CI) was used in lieu of hand separation of live and dead material. Chlorophyl was extracted overnight from a 250 mg sample of ground, dry forage with 20 ml of reagent grade ethanol. After filtration, transmittance of the extracted pigments was determined at 522 millimicrons, the absorption peak for the extract.

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The CI was calculated by the equation:

$$CI = \frac{\ln t}{\ln T} \times 100 \qquad [1]$$

where t = the percent light transmittance through the sample extractant, and,

T = the percent light transmittance through a standard sample.

September stockpiled and N fertilized tall fescue forage harvested in December 1975 was considered the standard for making comparisons. This sample was nearly 100% live leaf material. This method gave nearly constant and proportional extraction of pigments from the tall fescue forage and a linear index of pigment concentration in the extract.

Statistical computations were made by analysis of variance (3). Least significant values were calculated for comparisons found to be significantly different (P = 0.05) (12).

RESULTS

Winter Yield

The December dry matter (DM) yields of tall fescue decreased sharply each year with delays in dates of accumulating (stockpiling) tall fescue canopies (Table 1). When averaging the yields over stockpiling dates, the highest yield was obtained with N applied in September 1975. In 1976, yields peaked with the July and August N applications. There was a stockpiling × N date interaction, however, the highest yield for a given stockpiling date generally occurred when N was applied on the same date. When harvesting was delayed from December to February, there was a 60% loss in DM yield. The February DM yields (DMY_{Feb}, kg/ha) were highly correlated to the December DM yields (DMY_{Dec}) r = 0.95, n = 20).

$$DMY_{Feb} = 0.774\ DMY_{Dec} - 396. \qquad [2]$$

Summer Yield

The monthly summer production of tall fescue (Table 2) was generally highest with N applied in June or July. The yields averaged over N fertilizer treatments decreased progressively with later harvests in 1975, but not in 1976. Fertilizing with N usually caused production to peak in the month after N was applied.

Total Yield

The total regrowth DM yields decreased as stockpiling dates were delayed beyond July (Table 3). The yields averaged over stockpiling dates were generally highest for the June and July dates of applying N during both years, and lowest for August and September N applications in 1975 and 1976, respectively.

Total Nonstructural Carbohydrates

The TNC contents of December harvested forage generally increased as stockpiling was delayed from June to September (Table 4). TNC contents generally increased as N fertilization was delayed from June to September, but not as markedly as the changes due to canopy age. Over all treatments, the TNC content decreased 47% as harvesting was delayed from December to February (Data not shown). February TNC content (TNC_{Feb}) was correlated to December TNC content (TNC_{Dec}) (r = 0.88):

$$TNC_{Feb} = 0.502\ TNC_{Dec} + 1.49. \qquad [3]$$

There was a stockpiling date by N fertilization date interaction for the TNC contents in the December 1975 harvest.

The yield of TNC by the winter season decreased as stockpiling dates were delayed and increased as N fertilization was delayed for the December harvested canopies. Over all treatments, the TNC yield decreased by 64% as harvesting was delayed from December to February. February TNC yield ($TNCY_{Feb}$, kg/ha) was linearly correlated to December TNC yield ($TNCY_{Dec}$) (r = 0.92):

$$TNCY_{Feb} = 0.518\ TNCY_{Dec} - 73. \qquad [4]$$

Table 1. Yields of tall fescue accumulated by December from several spring-summer dates each with several dates of N application (112 kg/ha).

Date of applying 112 kg N/ha	Stockpiling periods				
	June to Dec.	July to Dec.	Aug. to Dec.	Sept. to Dec.	Avg.*
	kg/ha				
			1975		
No N	2,956†	1,121	880	521	1,369 a
June	4,864	2,599	1,177	793	2,358 b
July	4,393	3,031	1,666	698	2,448 b
Aug.	3,752	2,973	1,627	967	2,330 b
Sept.	3,971	2,947	2,295	2,021	2,808 c
Avg.*	3,987 a	2,534 b	1,529 c	1,000 d	
			1976		
No N	2,899††	1,837	923	447	1,526 a
June	4,297	2,863	843	377	2,095 b
July	4,852	3,688	1,263	591	2,598 d
Aug.	3,705	3,461	1,911	848	2,481 cd
Sept.	3,551	2,831	1,506	1,083	2,244 bc
Aug.*	3,861 a	2,936 a	1,289 b	669 b	

* Within stockpiling date and fertilization date averages, means followed by the same letter are not significantly different at the 0.05 level.
† L.S.D.$_{0.05}$ = 462 between treatment combinations in 1975.
‡ L.S.D.$_{0.05}$ = 1,787 between treatment combinations in 1976.

Table 2. Yields of tall fescue harvested at monthly intervals following several dates of N application (112 kg/ha).

Date of applying 112 kg N/ha	Harvest			
	July	Aug.	Sept.	Avg.*
	kg/ha			
		1975		
No N	873†	219	96	396 a
June	2,129	601	146	958 b
July	873	949	607	810 b
Aug.	873	219	381	491 a
Avg.*	1,187 d	496 b	308 a	
		1976		
No N	649‡	366	439	485 a
June	1,398	891	401	897 b
July	649	1,029	681	787 ab
Aug.	649	366	985	667 ab
Avg.*	836 ns	663 ns	626 ns	

* Within harvest date and fertilization date averages, means followed by the same letter are not significantly different at the 0.05 level.
† L.S.D.$_{0.05}$ = 219 between treatment combinations in 1975.
‡ L.S.D.$_{0.05}$ = 507 between treatment combinations in 1976.

However, a double logarithmic linear regression more closely described the relationship (r = 0.97):

$$\ln TNCY_{Feb} = 1.59 \ln TNCY_{Dec} - 4.671 \quad [5]$$

Crude Protein

The CP contents increased with delays in stockpiling dates and delays of N fertilization for stockpiled growth harvested during the 1975 to 1976 winter season (Table 5). For stockpiled fescue harvested in 1976 December, the CP content generally increased with delayed N fertilization; delayed stockpiling dates tended to increase the forage CP content, but not significantly when averaged over N treatments. The average loss of CP over all treatments was 0.5 units between December and February harvested canopies. The CP contents in February (CP_{Feb}) and December (CP_{Dec}) were highly correlated (r = 0.99):

$$CP_{Feb} = 1.03\ CP_{Dec} - 0.83. \quad [6]$$

The CP yields in the stockpiled forage decreased with delays in stockpiling dates and increased with delayed N fertilization for all harvests in both years. CP yield was 43% less in February than in December when averaged over all treatments. The CP yield in February (CPY_{Feb}, kg/ha) was closely correlated to the December yield (CPY_{Dec}) (r = 0.95):

$$CPY_{Feb} = 0.758\ CPY_{Dec} - 44. \quad [7]$$

Chlorophyl Index

The relative CI content in stockpiled tall fescue during 2 years increased with delayed stockpiling and delayed N fertilization dates when averaged over the factorial treatments (Table 6). When averaging all treatments, CI decreased 76% between the December and February harvested canopies during the 1975 to 1976 winter. The CI values in February (CI_{Feb}) and December (CI_{Dec}) were highly correlated (r = 0.89):

$$CI_{Feb} = 0.285\ CI_{Dec} - 2.6. \quad [8]$$

Interrelations of CP, TNC, and CI

The CP, TNC, and CI values of stockpiled tall fescue were highly correlated within the December and February dates of harvesting (Table 7). The three harvests differed significantly in the linear relations between CP and CI. The linear models of the CI vs. TNC relation also differed between harvests, but when pooled in a logarithmic model, the correlation increased. This did not occur with the CP vs. CI rela-

Table 3. Total yields (stockpiled plus monthly cuttings before stockpiling) of tall fescue for various stockpiling periods each with four dates of N application (112 kg/ha).†

Date of applying 112 kg N/ha	Stockpiling periods: June to Dec.	July to Dec.	Aug. to Dec.	Sept. to Dec.	Avg.*
	kg/ha				
			1975		
No N	2,956‡	1,994	1,970	1,708	2,155 a
June	4,864	4,728	3,907	3,669	4,292 d
July	4,393	3,905	3,925	3,564	3,947 cd
Aug.	3,752	3,846	2,870	2,591	3,265 b
Sept.	3,971	3,820	3,538	3,359	3,671 c
Avg.*	3,987 c	3,658 c	3,242 b	2,978 a	
			1976		
No N	2,899§	2,487	1,939	1,902	2,306 a
June	4,297	4,260	3,131	3,066	3,688 c
July	4,852	4,337	2,922	2,950	3,766 c
Aug.	3,705	4,110	2,926	2,935	3,419 c
Sept.	3,551	3,481	2,522	2,537	3,023 b
Avg.*	3,861 b	3,735 b	2,687 a	2,678 a	

* Within stockpiling date and fertilization date averages, means followed by the same letter are not significantly different at the 0.05 level.
† First cutting yield averaged 4,994 kg/ha on 3 June 1975.
‡ $L.S.D._{0.05}$ = 371 between treatment combinations in 1975.
§ $L.S.D._{0.05}$ = 1,307 between treatment combinations in 1976.

Table 4. Total nonstructural carbohydrates in tall fescue herbage at a December harvest as influenced by date of N application and date of initiation of stockpiling.

Date of applying 112 kg N/ha	Stockpiling periods: June to Dec.	July to Dec.	Aug. to Dec.	Sept. to Dec.	Avg.*
	%				
			1975		
No N	15.9†	19.1	19.6	19.6	18.5 a
June	14.7	18.0	21.2	22.8	19.2 ab
July	16.5	18.2	21.3	23.1	19.8 bc
Aug.	18.5	20.3	22.9	27.1	22.2 c
Sept.	20.3	23.3	27.2	30.5	25.3 d
Avg.*	17.2 a	19.8 b	22.4 c	24.6 d	
			1976		
No N	12.2‡	15.4	16.9	16.5	15.2 a
June	11.8	15.9	17.7	16.8	15.6 a
July	13.2	16.1	19.1	19.3	16.9 a
Aug.	17.0	19.1	22.5	26.1	21.1 b
Sept.	16.6	19.7	25.1	28.0	22.3 b
Avg.*	14.1 a	17.2 b	20.2 c	21.3 c	

* Within stockpiling date and fertilization date averages, means followed by the same letter are not significantly different at the 0.05 level.
† $L.S.D._{0.05}$ = 2.2 between treatment combinations in 1975.
‡ $L.S.D._{0.05}$ = 4.6 between treatment combinations in 1976.

Table 5. Crude protein in tall fescue herbage at a December harvest as influenced by date of N application and date of initiation of stockpiling.

Date of applying 112 kg N/ha	Stockpiling periods: June to Dec.	July to Dec.	Aug. to Dec.	Sept. to Dec.	Avg.*
	%				
			1975		
No N	9.3†	9.0	10.0	11.4	9.9 ab
June	8.2	8.9	8.8	11.2	9.3 a
July	9.7	9.5	10.2	10.7	10.0 bc
Aug.	9.7	10.6	10.6	10.9	10.4 c
Sept.	12.0	13.6	14.3	15.5	13.9 d
Avg.*	9.8 a	10.3 b	10.8 c	11.9 d	
			1976		
No N	7.4‡	8.4	8.8	9.2	8.4 a
June	8.2	8.4	8.8	9.4	8.7 ab
July	9.2	9.1	8.5	9.8	9.2 b
Aug.	9.9	11.0	10.7	11.0	10.6 c
Sept.	10.2	12.2	13.7	13.9	12.5 d
Avg.*	9.0 a	9.8 a	10.1 a	10.6 a	

* Within stockpiling date and fertilization date averages, means followed by the same letter are not significantly different at the 0.05 level.
† $L.S.D._{0.05}$ = 1.0 between treatment combinations in 1975.
‡ $L.S.D._{0.05}$ = 1.9 between treatment combinations in 1976.

Table 6. Chlorophyl indices in tall fescue herbage at a December harvest as influenced by date of N application and date of initiation of stockpiling.

Date of applying 112 kg N/ha	Stockpiling periods				
	June to Dec.	July to dec.	Aug. to Dec.	Sept. to Dec.	Avg.*
			1975		
No N	36†	38	42	42	40 a
June	31	40	42	51	41 a
July	40	45	48	52	46 b
Aug.	44	49	56	57	52 c
Sept.	64	78	89	100	83 d
Avg.*	43 a	50 b	56 c	61 d	
			1976		
No N	16‡	23	23	21	21 b
June	16	21	23	19	20 a
July	20	25	24	25	23 b
Aug.	25	37	34	36	33 c
Sept.	30	39	43	45	39 d
Avg.*	21 a	29 a	29 a	29 a	

* Within stockpiling date and fertilization date averages, means followed by the same letter are not significantly different at the 0.05 level.
† L.S.D.$_{0.05}$ = 8 between treatment combinations.
‡ L.S.D.$_{0.05}$ = 10 between treatment combinations.

Table 7. Correlation coefficients and regressions between crude protein (CP), total nonstructural carbohydrates (TNC), and chlorophyl index (CI) of stockpiled tall fescue.

Harvest dates	r	n	Regression
			CP vs. CI
1975 Dec.	0.96**	20	CI = 9.09 CP − 45.1
1976 Feb.	0.86	20	CI = 2.49 CP − 13.1
1976 Dec.	0.95	20	CI = 4.75 CP − 19.7
			CI vs. TNC
1975 Dec.	0.86	20	TNC = 0.26 CI + 7.7
1976 Feb.	0.84	20	TNC = 0.47 CI + 6.2
1976 Dec.	0.88	20	TNC = 0.56 CI + 3.0
All data pooled	0.92	60	ln TNC = 0.478 ln CI + 1.27
			CP vs. TNC
1975 Dec. + 1976 Dec.	0.83	40	TNC = 1.95 CP − 0.5
1976 Feb.	0.85	20	TNC = 0.98 CP + 2.1

** All r values are significant at the 0.01 level.

tionship. The linear models of CP vs. TNC were not significantly different for the December harvests, but the December harvests differed from the February harvest.

DISCUSSION

Total and December stockpiled tall fescue yields were highest from June and July stockpiling and N fertilization. However, with such early accumulation dates, the summer forage supply for grazing would be low. Reductions of total DM yields as stockpiling periods were shortened, can be attributed to frequent harvesting before stockpiling (9) and the declining December yields with progressively shorter regrowth periods.

Quality of stockpiled tall fescue decreased with age when harvested under the same climatic environment in December. However, Brown et al. (5) found that quality did not decrease with age as growth progressed into the fall, but thermal environments among autumn and winter harvests varied. Thus, under such conditions, quality was maintained due to changes in plant metabolism as temperatures decreased (5). Under both situations, constant or changing harvest environments, TNC and CP yields increase with age due to increases in dry matter yields (9, 13). During rapid plant growth, TNC and CP contents become diluted because of the rapid synthesis of structural material. Later, with slow growth during cool temperatures, TNC finally decline as photosynthetic efficiency decreases with age (6) and net photosynthesis per leaf declines with enlarging, old, dense canopies as dry matter yields increase (10).

Quality and DM yields were highly correlated for the December and February canopies, indicating that losses were proportional to initial (December) yield or quality. This is at variance with reported lower yield losses with increases in N fertilization (2). Fertilization with N increased yield and quality (CP and TNC contents) in early winter; absolute loss as winter progresses was higher in N vs. no N treatments, but the resulting yield and quality remained higher than if no N had been applied. A similar relationship occurs when evaluated in terms of absolute loss vs. residual quality and yield (2). Ocumpaugh and Matches (9) have shown that the loss of yield and quality are linear with advance of the winter season.

Treatments which increase the CP status of tall fescue forage (N fertilization and young age) decreased the freezing damage of stockpiled tall fescue as indicated by the positive correlation with CI values and green canopies observed in the field. This is confounded to some extent by the effect of N fertilization and young age increasing chlorophyl of forage and, thereby, the CI measurements. The stockpiled growths without N, with early N applications, and for old canopies, were low in CP and TNC.

The high positive correlation among CP, TNC, and CI in winter accumulated tall fescue at a given sampling date are probably associated to N fertilization affects on the CP status of the forage (8), which increased the chlorophyl content and, thereby, the photosynthetic activity. The cool temperatures allow the accumulation of photosynthate (TNC) since respiration is much lower than photosynthesis (5, 9). An increase in tissue K also occurs with N fertilization (8). These increases in CP, TNC, and K contents could explain increases in resistance to freezing injury.

The correlations between CP and TNC were similar in the December harvests during the 2 years, even though there was lower CI in the 1976 harvests (Tables 6, 7). The lower TNC and CP contents in the December 1976 vs. 1975, indicate that the initial CP loss may be from the cell sap in conjunction with TNC loss. For December samplings, weathering in 1976 was more severe than in 1975. The February 1976 harvest was severely weathered; TNC loss was probably associated with cell rupture and leaching by precipitation and metabolic activity within plant cells or microbes, whereas, that part of the protein fraction combined in cell membranes would not be readily soluble in water and less subject to leaching as compared to TNC fractions.

In grazing systems, tall fescue has special value for fall-winter grazing because the stockpiled green, rigid, and erect leaves that resist freezing damage maintain high yields and quality during fall and early winter.

Largest fall-winter yields can be obtained by the earliest stockpiling periods, but a subsequent loss in quality occurs. The compromise between yield and quality of stockpiled growth depends on the acreage of tall fescue available for stockpiling for winter grazing and the nutritional requirements of the livestock utilizing the forage (4).

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