

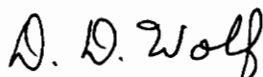
**Productivity and Quality of Tall Fescue and Switchgrass  
Under Two Harvest Managements and Different Harvest Intensities**

by

Dale Warren Ball

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in partial fulfillment of the requirements for the degree of  
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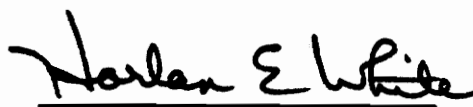
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D. D. Wolf, Chairman

Agronomy

(ABSTRACT)

Tall fescue (*Festuca arundinacea* Schreb.) often becomes dormant in the hot summer months. Switchgrass (*Panicum virgatum* L.) has potential to supplement the limited carrying capacity of tall fescue in mid-summer. The objective of this study was to determine the seasonal dry matter distribution and quality of tall fescue and switchgrass as influenced by different harvest managements. Switchgrass and tall fescue were studied on a fine-loamy, mixed, mesic Ultic Hapludalf of the Duffield soil series at Blacksburg, VA during 1987 and 1988. Normal harvest management included harvests taken from the first growth in spring until mid to late August. Delayed management included harvests taken from regrowth after a hay crop in mid-May for tall fescue and early June for switchgrass until mid to late August. Three and four harvest intensities were imposed on tall fescue and switchgrass, respectively. Plots were harvested in 1989 to determine the accumulative influence of treatments. Yield, crude protein, neutral detergent

fiber, and invitro dry matter digestibility were measured for each harvest of both species. Digestible yield and protein were calculated for each harvest. Clipping either switchgrass or tall fescue at any harvest intensity reduced potential yield compared to forage not clipped. Accumulated forage resulted in high yields but unsatisfactory quality. Delayed harvest management resulted in higher total yield than normal harvest management because of high hay yields. This study indicated that considerable overlap of forage production of tall fescue and switchgrass occurred in late spring but abundant high quality switchgrass was available in midsummer when available tall fescue was low. Switchgrass warrants consideration in southwest Virginia as a solution to the problem of limited cool-season forage in midsummer.

*Dedicated to*

*my wife Sarah, my sons Nathan and Steven,  
my Mom, the loving memory of my Father,  
and my wife's parents Walter and Claudia.*

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Moist, cool weather in spring and fall makes ideal growing conditions for cool-season grasses in southwest Virginia. However, cool-season grasses become dormant, at least making little growth, in the hot summer months causing a time of low productivity referred to as a "summer slump". Cool-season grasses produce 60 to 70 % of their growth by 1 June and nearly all of the remainder after they resume growth in early fall (Sharp and Gates, 1986). Warm-season grasses such as switchgrass, in contrast, produce 60 to 70 % of their growth in June, July, and August because they do not begin growing until mean daily temperatures approach 12 °C and stop growing before first frost in early fall (Jung et al., 1978).

Livestock producers, faced with low forage production and quality in midsummer, often choose one of two options for pasture management. One option is to limit stocking rate in spring, letting some forage accumulate for summer grazing. With this option, there is usually adequate forage quantity but quality is very low (Roundtree et al., 1974). The second option is to stock at the proper rate in the spring so that a maximum of high quality forage is used. This results in limited carrying capacity in midsummer and the need to sell some animals when forage production decreases. Switchgrass has the potential to supplement the limited carrying capacity of cool-season grasses in midsummer. Interest in the potential of switchgrass for midsummer forage production prompted research on management schemes.

Yield and stand persistence of switchgrass has been associated with clipping frequency. Aldous (1930) reported that yield of prairie grass varies

inversely with frequency of clipping. The greatest decrease of warm-season species occurred on plots clipped most frequently. High yields ( $8 \text{ Mg ha}^{-1} \text{ year}^{-1}$ ) of switchgrass were harvested in West Virginia on a soil of moderate to low fertility without fertilizer or limestone input on both one-cut and two-cuts per year clipping schedules but yield and vigor decreased when multiple cuttings were taken at six-week intervals or less (Balasko et al., 1984). In a study conducted in Georgia, Beaty and Powell (1976) concluded that 'Pangburn' switchgrass will tolerate one clipping per year and maintain yield and stands but clipping twice to a 15-cm stubble height when forage reaches either 61 cm or 91 cm will reduce yield, stand, and tiller height in succeeding years. Berg (1971) reported switchgrass did not survive the winter following frequent harvests to a 8-cm stubble height in spring and summer but speculated this was because sufficient energy reserves did not accumulate under a clipping regime as severe as is imposed on cool-season species.

Growth, yield, and quality of switchgrass are influenced by height of clipping. Aldous (1930) reported that the deleterious influence of frequent clipping on prairie grasses was partially eliminated by increasing height of clipping. Although lowest yields were recorded from plots clipped most frequently, prairie grass on these plots had the highest nutritive value. Aldous concluded that the increased nutritive value would not compensate for deleterious influences on stand and yield. He suggested this relationship would be more pronounced in arid regions where maintenance of stands is most important. Mowing switchgrass to a 3-cm stubble

height decreased yield, stopped reproductive shoots after inflorescence elevation, and initiated tillering from rhizomes and proaxes buds in a study at the Eastern Colorado Range Station (Sims et al., 1971). They also indicated that rhizomes of switchgrass plants clipped to a 3-cm stubble immediately turned upward and produced aerial shoots instead of remaining underground to produce new growth the following season. Beaty and Powell (1976) reported clipping switchgrass at 61 cm resulted in higher clone survival and tillers per clone the following year than clipping at 91 cm. They speculated this was due to a long period of regrowth after the last clipping at 61 cm enabling plants to resupply storage tissues. Beaty and Powell (1976) also concluded switchgrass can be utilized heavily in early spring if growing points are not removed and regrowth is allowed to accumulate. Anderson and Matches (1983) reported that less than 30% of total growth was available during July and August when first harvest was taken at the jointing stage and switchgrass cut to a 8-cm stubble always yielded more dry matter than when cut to a 23-cm stubble. They also reported regrowth of switchgrass was from continued primary shoot development when harvested to a 23-cm stubble because apical meristems were not removed but when harvested to a 8-cm stubble over half of the regrowth was from new crown tillers.

Timing of harvests and stage of maturity have been shown to influence growth and quality of switchgrass. Beaty and Powell (1976) reported weed contamination of switchgrass because of slow regrowth of tillers as the result of early clipping. In contrast, Anderson and Matches (1983) reported early harvests

of switchgrass resulted in higher quality forage and higher regrowth potential than harvests at later growth stages. Switchgrass can be harvested after frost with no harm to stand or yields the following year (Balasko et al., 1984; Beaty and Powell, 1976). Perry and Baltensperger (1979) reported rapid declines in leaf crude protein with each two week delay in harvest and suggested leaf maturation rather than increased stem growth was responsible for declining forage quality in perennial warm-season grasses. They also reported nitrogen fertilization increased dry matter yields, crude protein, and invitro dry matter digestibility of switchgrass.

Clipping management of established stands of switchgrass has not been studied in the southeast USA and more research is needed before these species can effectively supplement grazing operations in this area. Much has been published concerning management of established stands of tall fescue a cool-season species. Tall fescue was used in this study as a familiar species in order to compare differences in seasonal production and persistence. The objectives of this research included: *i.* determination of the influence of three harvest intensities on productivity and quality of tall fescue under two harvest management schedules, *ii.* determination of the influence of four harvest intensities on productivity and quality of switchgrass under two harvest management schedules, and *iii.* characterization of seasonal productivity and quality of tall fescue and switchgrass under the aforementioned managements.

## ***MATERIALS and METHODS***

Switchgrass and tall fescue were studied using established stands at the Virginia Polytechnic Institute and State University Agronomy Farm. The soil was a fine-loamy, mixed, mesic Ultic Hapludalf of the Duffield soil series. Nitrogen was applied at 78 kg ha<sup>-1</sup> to tall fescue plots each March and to switchgrass plots each May. Phosphorus and K were applied in spring of 1988 to all plots according to soil test recommendations. The experiment was a randomized complete block design with four replications containing a split-split-plot arrangement of treatments. Tall fescue and switchgrass were randomly assigned to main plots. Sub-plots were used for normal harvest management and delayed harvest management schedules. The normal management schedule included several harvest intensities taken from first growth in spring until about mid-to late August. The delayed management schedule included several harvest intensities taken after a hay crop in mid-May for tall fescue and early June for switchgrass until mid-to late August. Sub-sub-plots were randomly assigned to individual harvest intensities. Three harvest intensities imposed on tall fescue included: Heavy, (Forage clipped to leave a 5-cm stubble each time height reached 15 cm or at least each 3 weeks); Light, (Forage clipped to leave a 5-cm stubble each time height reached 30 cm or at least each 6 weeks); and Control, (Forage harvested at intervals from previously uncut areas to determine dry matter accumulation potential). Four harvest

intensities imposed on switchgrass included: Heavy, (Forage clipped to leave a 15-cm stubble each time height reached 40 cm or at least each 4 weeks); Medium, (Forage clipped to leave a 15-cm stubble each time height reached 56 cm or at least each 6 weeks); Light, (Forage clipped to leave a 25-cm stubble each time height reached 56 cm or at least each 4 weeks); and Control, (Forage cut to leave a 15-cm stubble at intervals from previously uncut areas to determine potential dry matter accumulation). Harvest intensity treatments were imposed during the spring and summer of 1987 and 1988. Tall fescue and switchgrass plots were cut to leave 5-cm and 15-cm stubbles, respectively each fall. Tall fescue plots were harvested on 15 May 1989 and switchgrass plots were harvested 8 June 1989 to determine the accumulative influence of treatments.

#### *Data collection and analyses*

Yields were determined by harvesting 0.5 by 3-m strips through the center of tall fescue and 0.5 by 6-m strips for switchgrass plots. Dry matter accumulation potential for the control harvest intensity was determined by harvesting 61 by 61-cm quadrats from previously uncut areas at each harvest. Samples were dried at 60 °C and weighed. Average extended leaf height was measured prior to each harvest. Tiller population of switchgrass was determined for each plot by counting tillers in a randomly placed 61 by 61-cm quadrat in spring of 1988 and 1989 to evaluate stand persistence as influenced by harvest treatments. Herbage samples for quality analysis were taken from every plot harvested at each harvest, dried,

and ground to pass a 1 mm screen. Percentage CP (Association of Official Analytical Chemists, 1975), NDF (Goering and Van Soest, 1970), and IVDMD (Tilley and Terry, 1963 as modified by Barnes, 1966) were determined for all herbage samples.

Data are presented by years, species, and harvest management schedules because dates of harvest differed between harvest management schedules and between tall fescue and switchgrass. Means and standard error of the mean were used for comparison of all measured variables. Yields, crop growth rate (CGR), forage height, stand density, CP, NDF, and IVDMD were considered random variables. Species, years, harvest management, and harvest intensity were considered fixed variables.

## ***RESULTS AND DISCUSSION***

### **Weather Conditions**

Below normal rainfall occurred in 1987 from May through August except for the first 10-day period in July. In 1988, rainfall was again below normal from May until mid July with the exception of the first 10-day period in June. Both summers were very dry and averages above long term average values are misleading, as they resulted from single thunderstorms during their respective 10-day period (Fig.1). Mean daily temperatures were not favorable for growth of switchgrass until May in either year, but were more favorable to growth of switchgrass than tall fescue during the summer months (Fig. 2). Mean daily air temperatures were generally 2 to 3 °C cooler during the spring and summer months of 1988 than 1987.

### **Dry Matter Yields**

Total yield of tall fescue harvested under the normal management schedule did not differ between years for the heavy or control harvest intensity treatments, but was about 27% less the second year for light harvest intensity (Table 1). Low yields for light harvest intensity the second year are probably the result of etiolation and death of leaves remaining after harvest due to a dramatic increase in canopy temperature after cutting a dense canopy back to 5 cm. Yield of tall fescue under

heavy harvest intensity was about 60% lower than the control both years and was 35% and 54% lower for light harvest intensity as compared to

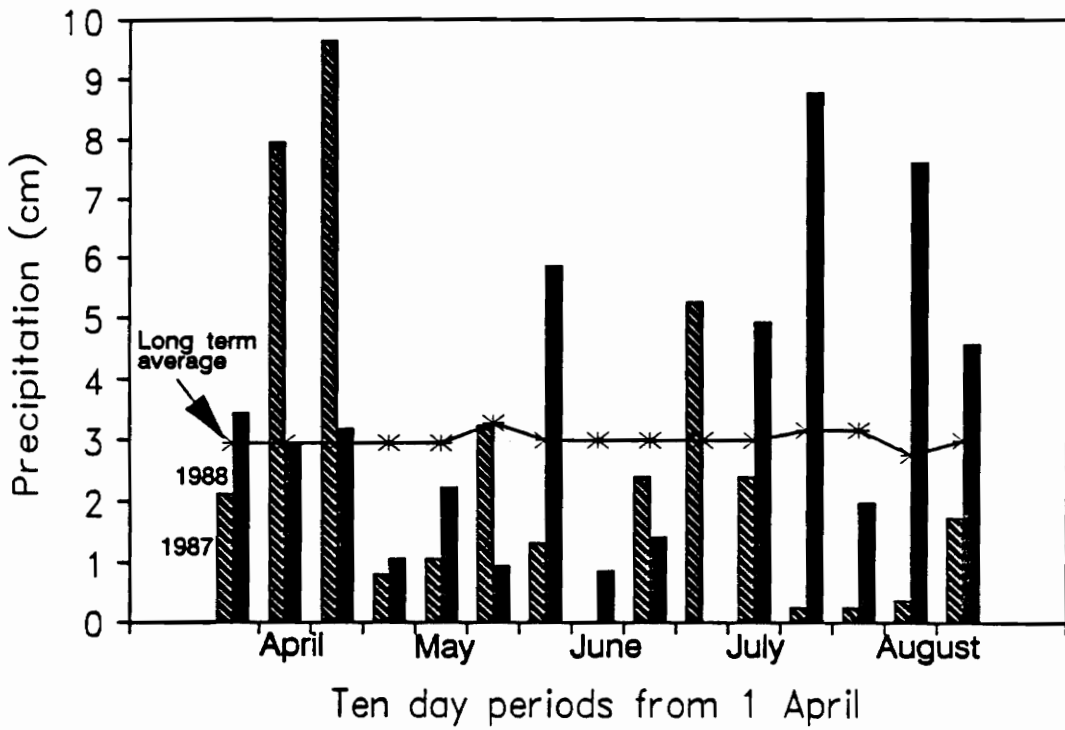


Fig. 1. Mean precipitation for 10-day intervals following 1 April in 1987 and 1988. Blacksburg, VA ( $37^{\circ} 11' N$ ,  $80^{\circ} 25' W$ , elevation 600m)

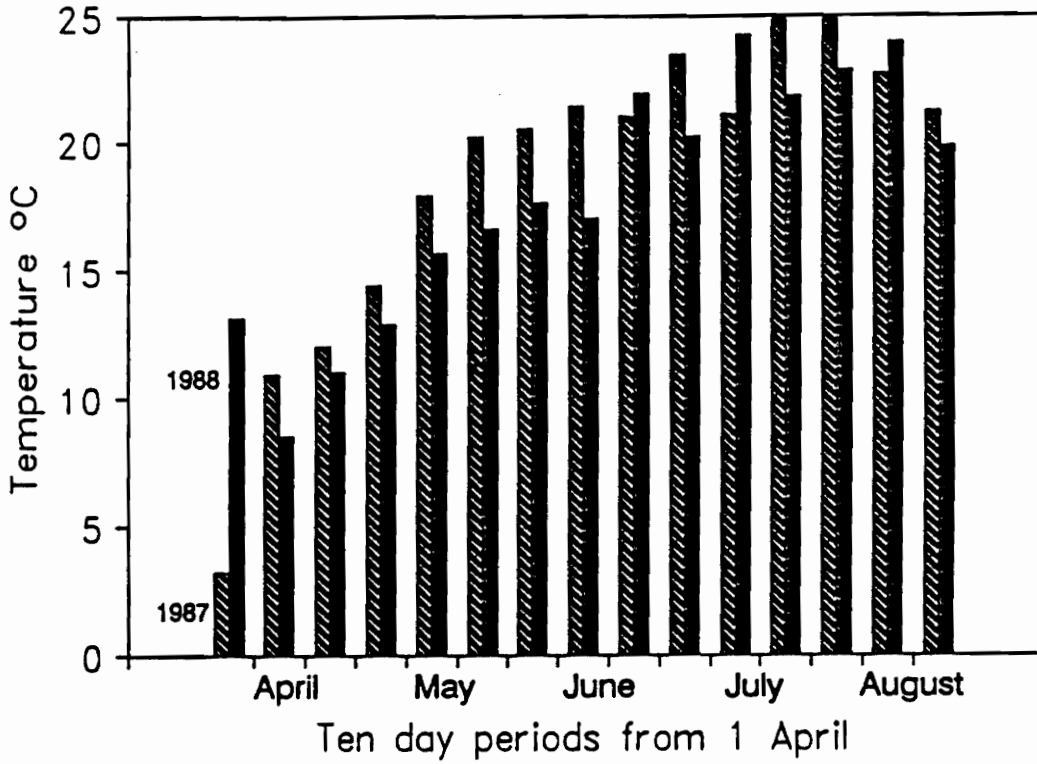


Fig. 2. Mean temperature for 10-day intervals following 1 April in 1987 and 1988. Blacksburg, VA ( $37^{\circ} 11' N$ ,  $80^{\circ} 25' W$ , elevation 600m)

Table 1. Total yield of tall fescue from two harvest managements in 1987 and 1988 as influenced by harvest intensity.

Harvest management	Year	Harvest intensity		
		Heavy	Light	Control†
		————— g m <sup>-2</sup> —————		
Normal	1987	288	466	722
	1988	264	339	744
Delayed				
Hay	1987	425	425	425
	1988	695	891	956
Regrowth	1987	252	343	329
	1988	90	110	127
Total	1987	677	768	754
	1988	785	1001	1083

SE‡ = 23

Analysis of variance	
Source of variance	Significance level
Harvest management	0.0001
Harvest intensity	0.0001
Year	0.0010
Harvest management*Intensity	0.0001
Harvest management*Year	0.0003
Harvest intensity*Year	0.0100

†Means reported for the control are for season-end harvest.

‡Standard error of the mean. Mean comparisons may be made by the difference  $\pm$  2.4 times the square root of the standard error of the difference.

the control in 1987 and 1988, respectively. Total yield of tall fescue under normal harvest management ranged from 288 to 722 g m<sup>-2</sup> in 1987 and from 264 to 744 g m<sup>-2</sup> in 1988 for heavy harvest intensity and the control respectively.

Total yield of tall fescue under delayed harvest management was higher for all harvest intensities in 1988 than 1987. This was the result of higher hay yields in 1988 since regrowth was lower for all harvest intensities in 1988 than 1987. Increased hay production in 1988 was probably the result of favorable spring soil moisture and cooler mean daily air temperatures, compared to 1987. Low (less than normal) regrowth in 1988 might be attributed to drought stress during the summer months. Regrowth of tall fescue after hay harvest was lower in 1987 for heavy harvest intensity as compared to light harvest intensity and the control which were not different. In 1988, regrowth after hay harvest was lower for heavy and light harvest intensity compared to the control but, heavy and light harvest intensities did not differ. Total yield of tall fescue under delayed management was higher than yield from normal harvest management for all harvest intensities both years except for the controls which were not different in 1987. Total seasonal yield for tall fescue under delayed harvest management ranged from 677 to 754 g m<sup>-2</sup> in 1987 and from 785 to 1083 g m<sup>-2</sup> in 1988 for heavy harvest intensity and the control, respectively.

Total yield of switchgrass harvested under normal management did not differ between years for medium or light harvest intensity. Heavy harvest intensity and the control yielded 23 and 15% less respectively, in 1988 than 1987 (Table 2).

Table 2. Total yield of switchgrass from two harvest managements in 1987 and 1988 as influenced by harvest intensity.

Harvest management	Year	Harvest intensity			
		Heavy	Medium	Light	Control†
		$\text{g m}^{-2}$			
Normal	1987	519	534	447	1776
	1988	397	552	392	1505
Delayed					
Hay	1987	516	516	516	516
	1988	347	259	341	802
Regrowth	1987	240	437	409	691
	1988	351	402	273	1128
Total	1987	756	953	925	1207
	1988	598	661	614	1930

SE‡ = 32

Analysis of variance

Source of variation	Significance level
Harvest management	0.0001
Harvest intensity	0.0001
Year	NS
Harvest management*intensity	0.0001
Harvest management*year	0.0001
Harvest intensity*year	0.0010

†Means reported for controls are for season-end harvest.

‡Standard error of least square means. Mean comparisons may be made by the difference  $\pm 2.4$  times the square root of the standard error of the difference.

Switchgrass clipped at any harvest intensity yielded from 63 to 75% less both years than the control which was not previously clipped. In 1987 total yield of switchgrass under normal harvest management for heavy and medium harvest intensity did not differ, but was lower for light harvest intensity. Heavy and light harvest intensity yields were not different in 1988 for normal harvest management but were lower than yield from medium harvest intensity. Low yield of light harvest intensity compared to other harvest intensities in 1987 was probably partly the result of more herbage left in field from 25 versus 15-cm stubble heights. Reduction of yield for heavy harvest intensity in 1988 compared to 1987 indicates early defoliation of switchgrass influenced subsequent yield of switchgrass more than frequency of clipping or stubble height since heavy and medium harvest intensity were both harvested 4 and 3 times in 1987 and 1988, respectively.

Hay yields for switchgrass in 1988 were lower than in 1987 for all clipping treatments but not for the control (Table 2). Total yield under delayed harvest management was lower in 1988 than 1987 for all harvest intensities. These results support earlier research concluding that repeated clipping of switchgrass reduces potential yield and subsequent yields (Balasko et al. 1984, Beaty and Powell 1976, and Newell 1968). Total yield of switchgrass from delayed harvest management was greater than total yield from normal harvest management for all harvest intensity treatments both years. This is in agreement with research in Iowa concluding that moderate defoliation of switchgrass in June can benefit grazing programs by providing high quality switchgrass in mid-June and relatively high

yields of switchgrass in summer when supplemental forage is most needed (George and Obermann 1989).

### **Stand Persistence**

Stands of tall fescue and switchgrass were vigorous and uniform at the beginning of this study and no tiller counts were made. In 1988 and 1989, after one and two years of clipping treatments there were no visible differences in stand of tall fescue except that switchgrass had begun invading the margins of adjacent tall fescue plots.

Tiller density of switchgrass after one year of clipping was lower for all harvest intensities than the control under both harvest managements (Table 3). Stand deterioration was most severe for heavy harvest intensity and least for light harvest intensity with medium harvest intensity being intermediate under normal harvest management. A harvest intensity by harvest management interaction occurred because stand density of switchgrass was lower under delayed harvest management than normal harvest management when clipped at light harvest intensity while stand densities were higher for each of the other harvest intensities under delayed harvest management. Tiller densities were not different between years for any harvest intensity under either harvest management except for light and medium harvest intensity under normal management. This interaction indicates that stubble height is important in conserving stands of switchgrass but

Table 3. Stand of switchgrass in 1988 and 1989, after one or two years respectively, as influenced by three harvest intensity treatments in two harvest management schedules.

Harvest management	Year	Harvest intensity			
		Heavy	Medium	Light	Control
		tillers m <sup>-2</sup>			
Normal	1988	410	520	901	1212
	1989	393	331	1014	1249
Delayed	1988	519	602	775	991
	1989	519	540	728	1034
SE† 28					

#### Analysis of variance

Source of variation	Significance
Harvest intensity	****
Harvest management	**
Harvest intensity X harvest management	****
Harvest intensity X Year	***
Harvest intensity X harvest management X Year	**

\*\*, \*\*\*, \*\*\*\* Represent significance at P=0.01, P=0.001, and P=0.0001 respectively.

† Standard error of the mean.

height before clipping is not important. These results are contrary to a previous report that stand of switchgrass was not adversely affected by height of defoliation (Anderson and Matches, 1983).

Clipping at any harvest intensity for two years reduced yield of tall fescue the spring of the third year compared to the control with the exception of heavy intensity under delayed management (Table 4). Reasons for this exception are not readily apparent. Yields of tall fescue after two years of treatments were lower on plots with delayed management for all harvest intensities compared to plots with normal management. This probably results from etiolation and death of tillers of tall fescue due to dramatic increase in soil and leaf temperature when a dense hay canopy is cut back to 5 cm. Similarly, tall fescue light harvest intensity plots yielded less the third year than any other harvest intensity under both harvest managements.

Switchgrass yield after two years of clipping treatments, like tall fescue, was less than yield of switchgrass not clipped (Table 4). Yield of switchgrass the third year was not different between harvest managements except for the controls. Lower yield for the switchgrass control under delayed management probably resulted because the control treatment under delayed management was harvested once each year for hay. Switchgrass yields on 1 June after two years of heavy or medium harvest intensity were not different but were less than yield of switchgrass harvested at light harvest intensity. This indicates that height of switchgrass before clipping is not important but a stubble height of 25-cm is better than 15-cm.

Table 4. Accumulative influence of different harvest managements and intensities on yield of tall fescue and switchgrass when measured on 1 June 1989.

Species	Harvest intensity	Harvest management	
		Normal	Delayed
—— g m <sup>-2</sup> ——			
Tall fescue	Heavy	310	226
	Light	292	185
	Control	376	231
Switchgrass	Heavy	172	198
	Medium	160	179
	Light	251	257
	Control	613	504
	SE†		11

Analysis of variance

Source of variance	Significance
Harvest intensity(Species)	0.0001
Harvest management	0.0001
Harvest management X Harvest intensity(Species)	0.0001

† Standard error of the mean.

### Forage Quality

Crude protein, neutral detergent fiber, and invitro dry matter digestibility from normal and delayed harvest management were similar for both tall fescue and switchgrass (Table 5). No significant interactions ( $P > 0.05$ ) occurred due to harvest management and harvest intensity so average quality data are presented from the combined analyses of the two harvest managements.

Crude protein ranged from 93 to 169 g kg<sup>-1</sup> for tall fescue and from 84 to 132 g kg<sup>-1</sup> for switchgrass (Table 5). Crude protein was higher for heavy than light harvest intensity for tall fescue. Switchgrass had higher crude protein for heavy than medium or light harvest intensity in 1987; however, in 1988 light harvest intensity had higher crude protein than either medium or heavy intensity which were not different. No explanation is apparent for this harvest intensity by year interaction. Light harvest intensity for switchgrass always had higher crude protein than medium intensity. This can be attributed to difference in stubble height between medium and light harvest intensity for switchgrass.

Protein concentration did not differ between species for the controls but was higher for tall fescue heavy and light harvest intensity than for any switchgrass harvest intensity in 1987. In 1988 crude protein of tall fescue heavy harvest intensity and switchgrass heavy, medium, and light harvest intensities were similar.

Table 5. Crude protein (CP), neutral detergent fiber (NDF), and invitro dry matter digestibility (IVDMD) concentration of tall fescue and switchgrass in 1987 and 1988 as influenced by harvest intensity.

Year	Species	Harvest Intensity	g kg <sup>-1</sup>		
			Protein	NDF	IVDMD
1987	Tall fescue	Heavy	169 ± 5 †	640 ± 9	701 ± 8
		Light	145 ± 6	662 ± 11	674 ± 10
		Control	93 ± 7	691 ± 12	641 ± 11
	Switchgrass	Heavy	128 ± 3	764 ± 9	638 ± 8
		Medium	106 ± 3	751 ± 10	639 ± 8
		Light	119 ± 2	752 ± 9	640 ± 8
		Control	84 ± 2	752 ± 8	583 ± 7
1988	Tall fescue	Heavy	136 ± 5	686 ± 9	644 ± 8
		Light	104 ± 6	681 ± 10	605 ± 10
		Control	-	-	-
	Switchgrass	Heavy	125 ± 2	738 ± 8	614 ± 7
		Medium	125 ± 2	743 ± 8	604 ± 7
		Light	132 ± 2	751 ± 8	602 ± 7
		Control	-	-	-
			Significance level		
ANOVA	Source of variation	Protein	NDF	IVDMD	
	HI(SPEC)	****	*	****	
	YEAR*HI(SPEC)	*	NS	NS	

\*,\*\*\*\* Represent significance at p=0.05 and p=0.0001, respectively.

† Means ± SE. Data averaged over all harvests except for the control where the value of the last harvest is reported.

However, tall fescue light harvest intensity had lower crude protein than any switchgrass clipping treatment. This was probably due to severe drought stress to tall fescue due to low spring soil moisture in 1988 and suggests an advantage to including switchgrass in grazing systems where moisture may limit pasture quality in summer.

Concentration of NDF was similar for both heavy and light harvest intensity of tall fescue in both years but was lower for heavy harvest intensity in 1987 than 1988 (Table 5). Neutral detergent fiber concentration was not different between harvest intensity treatments or years for switchgrass. However, NDF concentration was always lower for tall fescue compared to any switchgrass harvest intensity in either year. This indicates intake and digestibility may be higher for tall fescue than switchgrass.

Invitro dry matter digestibility of tall fescue was always higher for heavy than light harvest intensity (Table 5). In 1988, IVDMD was approximately 6% lower for each clipping treatment than in 1987. There were no differences between IVDMD of switchgrass for either harvest intensity or year but IVDMD was higher for tall fescue than switchgrass both years with the exception of light harvest intensity of tall fescue in 1988. Differences of IVDMD between tall fescue and switchgrass here are difficult to evaluate since IVDMD in switchgrass may under estimate animal performance due to selective grazing and poor prediction relationships between IVDMD and digestible dry matter (Griffin et al., 1980, Jung et al., 1985,

and Jung et al., 1988). Perhaps, absolute differences among in vivo data would be less than indicated in this study.

### **Seasonal Productivity and Quality**

One of the objectives of this study was to characterize the seasonal productivity and quality of tall fescue and switchgrass and to determine if production of switchgrass could be delayed by harvest management to better fit the period of greatest forage need. Considerable overlap of forage production of tall fescue and switchgrass before 1 June is evident from the crop growth rates (Tables 6 and 7) and yields (Figure 3). Under normal harvest management maximum growth rate of tall fescue occurred in mid to late May for all harvest intensities both years, after which growth rate declined sharply. However, approximately 260 g m<sup>-2</sup> available forage was harvested in mid June which could have been grazed. In 1987, maximum growth rate of switchgrass for all clipping treatments under normal harvest management also occurred in mid to late May but growth continued throughout the month of July. Approximately 200 and 140 g m<sup>-2</sup> of switchgrass under normal harvest management was available from medium and light harvest intensities respectively in mid August when there was little available tall fescue. Available tall fescue in mid July ,under delayed management, in 1987 was about 300 and 80 g m<sup>-2</sup> for light and heavy harvest intensities respectively.

Table 6. Growth rate (CGR) of tall fescue and switchgrass between harvest dates, under different harvest managements and intensities in 1987.

Harvest management	Species	Harvest date	Harvest intensity			
			Heavy	Medium	Light	Control
			CGR (g m <sup>-2</sup> day <sup>-1</sup> )			
Normal	Tall fescue	18 April	0.8 ±0.1 †			0.9 ±0.1
		28	3.7 ±0.6			
		5 May			4.2 ±0.2	7.5 ±0.4
		11	5.2 ±0.3			
		22				16.6 ±0.9
		26	5.7 ±0.6			
		10 June			7.2 ±0.7	
		15				7.6 ±1.6
		7 July	1.7 ±0.2		2.3 ±0.2	
	15				3.8 ±1.7	
	Switchgrass	11 May	3.6 ±0.2			3.4 ±0.2
		20			3.0 ±0.2	
		22		5.4 ±0.6		7.1 ±1.0
		29	9.4 ±0.5			
		3 June			8.4 ±0.8	31.1 ±3.2
		17		7.5 ±0.2		
		29	6.0 ±0.2			
		1 July			5.0 ±0.1	16.7 ±2.4
31					25.0 ±0.6	
Delayed	Tall fescue	15 June	5.9 ±0.4			6.0 ±0.4
		10 July			6.5 ±0.3	7.0 ±0.4
		13	3.0 ±0.1			
		13 Aug.				-0.2 ±0.5
		24	0.6 ±0.1		0.5 ±0.1	
		11 Sep.				-0.3 ±0.4
	Switchgrass	13 July	10.4 ±0.2			10.1 ±0.7
		21		14.0 ±0.4	13.2 ±0.5	24.6 ±1.7
		13 Aug.				11.0 ±0.6
		25				1.4 ±0.2

† Means ± standard error of the mean.

Table 7. Growth rate (CGR) of tall fescue and switchgrass between harvest dates, under different harvest managements and intensities in 1988.

Harvest management	Species	Harvest date	Harvest intensity			
			Heavy	Medium	Light	Control
			CGR (g m <sup>-2</sup> day <sup>-1</sup> )			
Normal	Tall fescue	21 April	2.3 ±0.1 †			2.7 ±0.2
		3 May			6.9 ±0.4	17.2 ±0.7
		13	6.8 ±0.3			
		22				16.8 ±1.2
		11 June	1.7 ±0.1			
		13				6.3 ±0.4
		27			3.0 ±0.2	
	Switchgrass	2 July	0.9 ±0.2			
		15				0.7 ±0.1
		27 May				20.9 ±0.3
		31	4.0 ±0.6			
		8 June			3.9 ±0.1	
		10		5.2 ±0.2		
		11				15.8 ±0.9
		27	3.9 ±0.1		6.0 ±0.3	15.2 ±1.9
		16 July		4.2 ±0.1		
		7 Aug.	4.0 ±0.6			
Delayed	Tall fescue	8			2.9 ±0.2	
		16			1.0 ±0.3	
		17		5.8 ±0.4		
		27 June	1.4 ±0.1			1.4 ±0.3
		16 July			1.2 ±0.2	1.0 ±0.5
	Switchgrass	1 Aug.	0.6 ±0.1			
		26				1.3 ±0.1
		1 Sep.	0.6 ±0.1		0.9 ±0.1	
		2 July	7.1 ±0.6			9.2 ±0.2
		9		6.3 ±0.5	2.2 ±0.1	
Switchgrass	24				8.0 ±0.4	
	9 Aug.			6.9 ±0.3		
	13	5.1 ±0.1				
	17		6.1 ±0.2			
	22				16.0 ±0.5	
	13 Sep.				8.2 ±0.8	
	28				2.9 ±0.7	

†Means ± standard error of the mean.

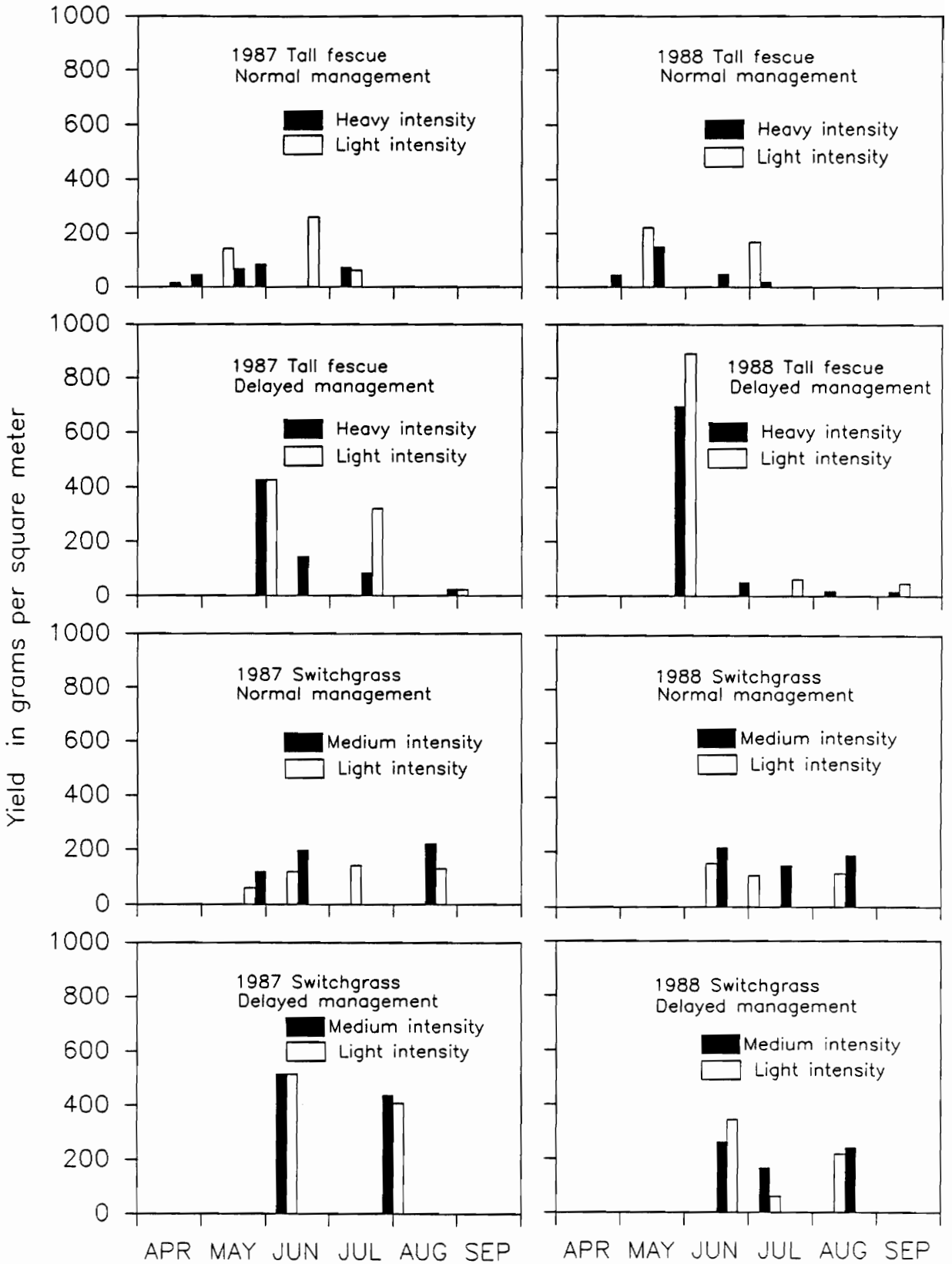


Fig. 3. Yield of tall fescue and switchgrass from two harvest managements and different harvest intensities in 1987 and 1988.

Switchgrass under delayed management in 1987 had about 400 g m<sup>-2</sup> for both medium and light harvest intensity in late July. In 1988, 200 g m<sup>-2</sup> of tall fescue was available under normal management at light harvest intensity in late June after which very little forage was available for the remainder of the summer. Torres (1983), noted that abundant tall fescue forage in spring is often wasted and suggested conserving some of the forage as silage to be fed to livestock in winter. His proposal, a 12-month plan, required that livestock graze regrowth of tall fescue until August. During the term of Torres study, rainfall was about 3 cm above the long term average for each 10-day period during summer months while in this study weather conditions were dry both years. This study emphasizes that summers in southwest Virginia are sometimes hot and dry making growing conditions for summer production of cool-season grasses like tall fescue unfavorable. However, in May tall fescue had high hay yields of approximately 700 and 900 g m<sup>-2</sup> for heavy and light harvest intensity, respectively, under delayed management represent forage that could be preserved and fed to livestock during the summer months. Maximum growth rate of switchgrass in 1988 was from 22 to 57% lower than in 1987. Even with reduced productivity, in 1988 as compared to 1987 about 200 g m<sup>-2</sup> of switchgrass was available from medium harvest intensity under both harvest managements in mid-August. Growth rate of switchgrass was always higher than growth rate of tall fescue during the month of July and August and thus switchgrass warrants consideration in southwest Virginia as a solution to the problem of low available cool-season forage in mid-summer.

Crude protein of tall fescue under normal management at heavy harvest intensity ranged from 136 to 294 g kg<sup>-1</sup> and at light harvest intensity ranged from 98 to 183 g kg<sup>-1</sup> in 1987 (Table 8). Crude protein of switchgrass under normal management in 1987 ranged from 105 to 201 g kg<sup>-1</sup> for heavy harvest intensity, 78 to 145 g kg<sup>-1</sup> for medium harvest intensity, and 94 to 160 g kg<sup>-1</sup> for light harvest intensity. Under delayed management in 1987 crude protein of tall fescue ranged from 131 to 189 g kg<sup>-1</sup> for heavy harvest intensity and from 137 to 138 g kg<sup>-1</sup> for light harvest intensity. Switchgrass was harvested only once for each clipping treatment under delayed management in 1987. Crude protein was 115, 92, and 103 g kg<sup>-1</sup> for heavy, medium, and light harvest intensity, respectively. The control treatments indicate, that for each species crude protein declines as the forage matures. Crude protein generally declined with each harvest for both species. Tall fescue harvested at heavy intensity on 28 April and at light intensity on 10 June were exceptions since crude protein was higher for their next harvest. No explanation is apparent for this difference on 28 April and 11 May but perhaps more favorable soil moisture was responsible for increased crude protein on 7 July for light harvest intensity (Fig. 1).

Seasonal trends for crude protein in 1988 were similar to 1987 (Table 9). Crude protein of both tall fescue and switchgrass decreased each month but other comparisons between years were not possible because harvest dates were not the same. Comparisons between species were difficult because of different

Table 8. Crude protein concentration of tall fescue and switchgrass under different harvest managements and intensities in 1987.

Harvest management	Species	Harvest date	Harvest intensity			
			Heavy	Medium	Light	Control
			Protein (g kg <sup>-1</sup> )			
Normal	Tall fescue	18 April	294 ± 1 †			
		28	154 ± 2			
		5 May			183 ± 6	
		11	170 ± 3			
		22				101 ± 5
		26	150 ± 6			
		10 June			98 ± 4	
		15				64 ± 4
		7 July	136 ± 4		132 ± 3	
	15				62 ± 2	
	Switchgrass	11 May	201 ± 5			
		20			160 ± 1	
		22		145 ± 3		
		29	164 ± 2			
		3 June			153 ± 3	119 ± 3
		17		119 ± 4		
		29	132 ± 2			
		1 July			129 ± 3	82 ± 3
31					51 ± 2	
10 Aug.			94 ± 6			
11	105 ± 3	78 ± 1				
28				--		
Delayed	Tall fescue	15 June	189 ± 1			
		10 July			138 ± 6	
		13	168 ± 6			95 ± 2
		13 Aug.				--
		24	131 ± 2		137 ± 2	
	11 Sep.				96 ± 6	
	Switchgrass	13 July	115 ± 4			
		21		92 ± 6	103 ± 3	
		13 Aug.				64 ± 3
25					66 ± 4	

† Means ± standard error of the mean.

Table 9. Crude protein concentration of tall fescue and switchgrass under different harvest managements and intensities in 1988.

Harvest management	Species	Harvest date	Harvest intensity			
			Heavy	Medium	Light	Control
			Protein (g kg <sup>-1</sup> )			
Normal	Tall fescue	21 April	204 ± 4 †			
		3 May			139 ± 5	
		13	142 ± 4			
		22				--
		11 June	123 ± 4			
		13				--
		27			78 ± 4	
	Switchgrass	2 July	120 ± 6			
		15				--
		27 May				--
		31	146 ± 2			
		8 June			151 ± 4	
		10		136 ± 6		
		11				--
		27	133 ± 4		132 ± 3	--
		16 July		123 ± 4		
		7 Aug.	118 ± 1			
8			114 ± 2			
16				--		
17		104 ± 3				
Delayed	Tall fescue	27 June	171 ± 3			--
		16 July			100 ± 8	--
		1 Aug.	152 ± 1			
		26				--
		1 Sep.	138 ± 4		120 ± 3	
	Switchgrass	2 July	117 ± 1			--
		9		116 ± 2	129 ± 2	
		24				--
		9 Aug.			108 ± 1	
		13	104 ± 2			
		17		101 ± 5		
		22				--
		13 Sep.				--
28				--		

†Means ± standard error of the mean.

criteria for harvest intensity and different harvest dates but crude protein was generally lower for switchgrass than tall fescue during the summer months.

Trends of NDF concentration in tall fescue and switchgrass were similar (Tables 10 and 11). Neutral detergent fiber increased with each harvest after first harvest for all harvest intensities. Control treatments for both species show increase in fiber as forages matured. Tall fescue always had lower NDF concentration than switchgrass. Intake may be limited by fiber in forages when NDF concentration exceeds  $600 \text{ g kg}^{-1}$  (Van Soest, 1965 and Griffin et al., 1980). Intake of animals grazing switchgrass may be limited by distention since NDF concentration of switchgrass was always over  $600 \text{ g kg}^{-1}$ . Selective grazing of leafy material by livestock may increase forage intake above levels indicated by this study.

Trends of IVDMD for tall fescue and switchgrass were similar (Tables 12 and 13). The IVDMD of both species declined with each successive harvest in 1988. In 1987, IVDMD of tall fescue at first harvest was lower for light than heavy harvest intensity under both harvest managements as expected (Table 12). However, IVDMD of light and heavy harvest intensity were similar at first harvest in 1988 (Table 13). This probably resulted from reduced growth in 1988 due to droughty soil. In contrast, IVDMD of switchgrass was not different between harvest intensities either year. These results were not expected considering the different stubble heights between harvest intensities. These results are in agreement with

Henry et al. (1976) who reported that cutting height had no influence on digestibility of switchgrass also Perry and Baltensperger (1976) who reported

Table 10. Neutral detergent fiber (NDF) concentration of tall fescue and switchgrass under different harvest managements and intensities in 1987.

Harvest management	Species	Harvest date	Harvest intensity			
			Heavy	Medium	Light	Control
			NDF (g kg <sup>-1</sup> )			
Normal	Tall fescue	18 April	515 ± 8 †			
		28	--			
		5 May			553 ± 12	
		11	558 ± 9			
		22				687 ± 18
		26	672 ± 6			
		10 June			702 ± 19	
		15				706 ± 14
		7 July	756 ± 4		749 ± 17	
	15				742 ± 2	
	Switchgrass	11 May	679 ± 9			
		20			742 ± 15	
		22		747 ± 12		
		29	766 ± 9			
		3 June			770 ± 5	740 ± 18
		17		748 ± 12		
		29	775 ± 8			
		1 July			759 ± 13	798 ± 11
		31				762 ± 8
10 Aug.				749 ± 3		
11	697 ± 13	721 ± 8				
28				--		
Delayed	Tall fescue	15 June	672 ± 8			
		10 July			710 ± 13	
		13	677 ± 6			
		13 Aug.				706 ± 19
		24	656 ± 11		660 ± 17	
	11 Sep.				686 ± 10	
	Switchgrass	13 July	740 ± 12			
		21		767 ± 5	753 ± 7	
		13 Aug.				730 ± 14
25					801 ± 6	

† Means ± standard error of the mean.

Table 11. Neutral detergent fiber (NDF) concentration of tall fescue and switchgrass under different harvest managements and intensities in 1988.

Harvest management	Species	Harvest date	Harvest intensity			
			Heavy	Medium	Light	Control
			NDF (g kg <sup>-1</sup> )			
Normal	Tall fescue	21 April	558 ± 6 †			
		3 May			578 ± 6	
		13	643 ± 2			
		22				--
		11 June	761 ± 18			
		13				--
		27			702 ± 14	
		2 July	741 ± 12			
		15				--
	Switchgrass	27 May				--
		31	708 ± 7			
		8 June			745 ± 7	
		10		735 ± 16		
		11				--
		27	723 ± 16		745 ± 8	--
		16 July		774 ± 10		
		7 Aug.	793 ± 8			
		8			754 ± 8	
16				--		
17		741 ± 10				
Delayed	Tall fescue	27 June	687 ± 12			--
		16 July			762 ± 14	--
		1 Aug.	723 ± 8			
		26				--
		1 Sep.	633 ± 11		651 ± 8	
	Switchgrass	2 July	770 ± 6			--
		9		736 ± 14	731 ± 8	
		24				--
		9 Aug.			760 ± 6	
		13	710 ± 19			
		17		778 ± 12		
		22				--
		13 Sep.				--
28				--		

†Means ± standard error of the mean.

Table 12. Invitro dry matter digestibility (IVDMD) of tall fescue and switchgrass under different harvest managements and intensities in 1987.

Harvest management	Species	Harvest date	Harvest intensity			
			Heavy	Medium	Light	Control
			IVDMD (g kg <sup>-1</sup> )			
Normal	Tall fescue	18 April	802 ±11†			
		28	788 ±16			
		5 May			742 ±10	
		11	733 ±20			
		22				678 ±12
		26	736 ±13			
		10 June			686 ±22	
		15				607 ±17
		7 July	667 ±16		671 ±21	
	15				580 ±16	
	Switchgrass	11 May	748 ±13			
		20			700 ±25	
		22		719 ±22		
		29	697 ± 7			
		3 June			696 ±12	672 ±18
		17		655 ± 9		
		29	660 ±16			
		1 July			667 ±14	603 ±12
31					523 ± 9	
10 Aug.			577 ±20			
11	634 ±21	571 ±11				
28				--		
Delayed	Tall fescue	15 June	701 ±18			
		10 July			673 ±15	
		13	707 ±15			
		13 Aug.				659 ±20
		24	592 ±19		581 ±14	
	11 Sep.				577 ±11	
	Switchgrass	13 July	621 ±18			
		21		623 ±17	621 ±27	
		13 Aug.				543 ±25
25					484 ±13	

† Means ± standard error of the mean.

Table 13. Invitro dry matter digestibility (IVDMD) of tall fescue and switchgrass under different harvest managements and intensities in 1988.

Harvest management	Species	Harvest date	Harvest intensity			
			Heavy	Medium	Light	Control
			IVDMD (g kg <sup>-1</sup> )			
Normal	Tall fescue	21 April	725 ±19 †			
		3 May			706 ±13	
		13	675 ±15			
		22				--
		11 June	656 ±25			
		13				--
		27			546 ±24	
	Switchgrass	2 July	625 ±19			
		15				--
		27 May				--
		31	668 ±25			
		8 June			647 ±12	
		10		636 ±16		
		11				--
		27	631 ±21		612 ±9	
		16 July		574 ±10		
		7 Aug.	593 ±8			
Delayed	Tall fescue	8			554 ±9	
		16			--	
		17		545 ±8		
		27 June	622 ±23			--
	Switchgrass	16 July			593 ±8	--
		1 Aug.	633 ±26			--
		26				--
		1 Sep.	652 ±11		603 ±10	
		2 July	618 ±28			--
		9		613 ±23	618 ±22	
		24				--
9 Aug.			546 ±7			
13	573 ±11					
17		534 ±16				
22				--		
13 Sep.				--		
28				--		

†Means ± standard error of the mean.

that leaf maturation was primarily responsible for declining digestibility of switchgrass rather than increasing plant development.

### **Digestible Yield and Protein Yield**

Digestible yield of tall fescue harvested under normal management did not differ between years for the heavy harvest intensity but was about 24% less the second year for light harvest intensity (Table 14). In 1987 and 1988 digestible yield of tall fescue was lower for heavy harvest intensity than light harvest intensity under both harvest managements. Total digestible yield of tall fescue was higher for delayed harvest management than normal harvest management for all treatments in both years.

Digestible yield of switchgrass light harvest intensity under normal harvest management in 1987 was lower than for heavy or medium harvest intensity which were not different (Table 15). In 1988, digestible yield of switchgrass under normal harvest management was higher for medium harvest intensity than for heavy or light harvest intensity. Digestible yield of switchgrass under normal management was not different between years for medium harvest intensity but declined 30% and 20% in 1988 compared to 1987 for heavy and light harvest intensities respectively. Switchgrass medium harvest intensity always yielded more digestible dry matter than heavy or light harvest intensities except in 1987 under normal harvest management when digestible yield was similar for heavy and medium intensities.

Table 14. Total digestible yield of tall fescue from two harvest managements in 1987 and 1988 as influenced by harvest intensity.

Harvest management	Year	Harvest intensity		
		Heavy	Light	Control†
		g m <sup>-2</sup>		
Normal	1987	209	325	419
	1988	178	248	--
Delayed				
Hay	1987	288	288	288
	1988	471	603	--
Regrowth	1987	175	229	206
	1988	57	66	--
Total	1987	463	517	494
	1988	528	669	--

SE<sub>t</sub> = 10

Analysis of variance	Significance level
Source of variance	
Harvest management	0.0001
Harvest intensity	0.0001
Year	0.0001
Harvest management*Intensity	0.0001
Harvest management*Year	0.0001
Harvest intensity*Year	0.01

†Means reported for the control are for season end harvest.

‡Standard error of the mean. Mean comparisons may be made by the difference  $\pm$  2.4 times the square root of the standard error of the difference.

Table 15. Total digestible yield of switchgrass from two harvest managements in 1987 and 1988 as influenced by harvest intensity.

Harvest management	Year	Harvest Intensity			
		Heavy	Medium	Light	Control†
		g m <sup>-2</sup>			
Normal	1987	349	339	292	895
	1988	245	325	238	--
Delayed					
Hay	1987	346	346	346	346
	1988	233	174	229	--
Regrowth	1987	149	271	254	376
	1988	207	228	154	--
Total	1987	495	617	600	722
	1988	440	574	383	--
SE‡ = 9					

## ANOVA

Source of variation	Significance level
Harvest management	0.0001
Harvest intensity	0.0001
Year	0.0001
Harvest management*intensity	0.0001
Harvest management*year	0.01
Harvest intensity*year	0.001

†Means reported for controls are for season end harvest.

‡Standard error of the mean. Mean comparisons may be made by the difference  $\pm$  2.4 times the square root of the standard error of the difference.

Total digestible yield of switchgrass was higher for delayed harvest management than normal harvest management for all treatments in both years.

Crude protein yield of heavy harvest intensity of tall fescue under normal harvest management did not differ between years but was lower in 1988 than 1987 for light harvest intensity (Table 16). Crude protein yield of tall fescue was lower for heavy harvest intensity than light harvest intensity in 1988 for hay and total season growth (hay plus regrowth) under delayed management and in 1987 under normal management. Crude protein yield of tall fescue in all other cases did not differ between heavy and light harvest intensity. Tall fescue always yielded more crude protein under delayed management than normal management.

Protein yield of switchgrass under normal management did not differ between years except for heavy harvest intensity which was lower in 1988 than 1987 (Table 17). Protein yield of hay under delayed management was lower in 1988 than 1987 for all harvest intensities. Regrowth of switchgrass under delayed management did not differ for medium harvest intensity but was higher for heavy and lower for light harvest intensity in 1988 than 1987. Protein yield was higher for delayed harvest management than normal harvest management for all harvest intensities in both years.

Table 16. Total crude protein yield of tall fescue from two harvest managements in 1987 and 1988 as influenced by harvest intensity.

Harvest management	Year	Harvest intensity		
		Heavy	Light	Control†
		————— g m <sup>-2</sup> —————		
Normal	1987	46	60	45
	1988	39	44	--
Delayed				
Hay	1987	43	43	43
	1988	70	89	--
Regrowth	1987	44	47	30
	1988	12	12	--
Total	1987	87	90	73
	1988	82	101	--
SE‡ = 2				
Analysis of variance				
Source of variance		Significance level		
Harvest management		0.0001		
Harvest intensity		0.0001		
Year		0.0001		
Harvest management*Intensity		0.05		
Harvest management*Year		0.0001		

†Means reported for the control are for season end harvest.

‡Standard error of the mean. Mean comparisons may be made by the difference  $\pm$  2.4 times the square root of the standard error of the difference.

Table 17. Total crude protein yield of switchgrass from two harvest managements in 1987 and 1988 as influenced by harvest intensity.

Harvest management	Year	Harvest intensity			
		Heavy	Medium	Light	Control†
		g m <sup>-2</sup>			
Normal	1987	73 ‡	58	57	88
	1988	52	67	50	--
Delayed					
Hay	1987	61	61	61	61
	1988	41	32	40	--
Regrowth	1987	27	40	42	46
	1988	38	43	31	--
Total	1987	88	101	103	722
	1988	79	75	71	--
SE‡ = 2					

## ANOVA

Source of variation	Significance level
Harvest management	0.0001
Harvest intensity	0.0001
Year	0.05
Harvest management*intensity	0.0001
Harvest management*year	0.01
Harvest intensity*year	0.0001

†Means reported for controls are for season end harvest.

‡Standard error of the mean. Mean comparisons may be made by the difference  $\pm$  2.4 times the square root of the standard error of the difference.

## ***CONCLUSIONS***

Clipping either switchgrass or tall fescue at any harvest intensity reduced potential yield for the summer months compared to forage not harvested. However, no clipping results in high accumulated yields but unsatisfactory forage quality. In general, delayed harvest management resulted in higher total yield than normal harvest management for both species because of high hay yields taken before regrowth. Total yield of light harvest intensity of tall fescue was higher than heavy harvest intensity under both harvest managements. Total yield of switchgrass was higher for medium harvest intensity under both harvest managements as compared to heavy or light harvest intensities. Yields from final harvest in 1989 indicate that heavy harvest intensity is better for tall fescue than light harvest intensity. Yields from final harvest and tiller densities in 1989 indicate that height before cutting is not important for stand preservation of switchgrass but that a 25-cm stubble is better than 15-cm stubble.

Crude protein, NDF, and IVDMD concentrations were similar between harvest managements at each harvest intensity for both species. In general crude protein and IVDMD were higher and NDF lower for tall fescue than switchgrass. Estimates of differences in animal performance between tall fescue and

switchgrass are difficult to evaluate since apparently whole plant analysis of IVDMD in switchgrass may under estimate animal performance due to selective grazing and poor prediction relationships between IVDMD and digestible dry matter (Griffin et al., 1980, Jung et al., 1985, and Jung et al., 1988). Forage quality was generally best for heavy harvest intensity of both species. This study indicates that intake of animals grazing switchgrass may be limited by distention since NDF concentration of switchgrass was always over 690 g kg<sup>-1</sup>. However, forage intake of animals grazing switchgrass may be higher than indicated by this study due to selective grazing of leafy material. In general, protein yield of tall fescue between heavy and light harvest intensity did not differ but total protein under delayed harvest management was always higher compared to normal harvest management. Digestible yield of tall fescue was always higher for light harvest intensity than heavy harvest intensity. Switchgrass harvested at medium intensity generally yielded more digestible dry matter than heavy or light harvest intensities. Delayed harvest management always had higher total digestible yield than normal harvest management for both species.

Seasonal trends for crude protein, IVDMD, and NDF were similar for both species. Crude protein and IVDMD decreased and NDF increased as the forages matured. This study indicated that considerable overlap of forage production of tall fescue and switchgrass occurred in late spring but abundant high quality switchgrass was available in midsummer when available tall fescue was low.

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*Appendix*

**Additional Information**

Appendix Table 18. Acid detergent fiber (ADF) of tall fescue and switchgrass under different harvest managements and intensities in 1987.

Harvest management	Species	Harvest date	Harvest intensity			
			Heavy	Medium	Light	Control
			ADF (g kg <sup>-1</sup> )			
Normal	Tall fescue	18 April	201 ± 8 †			
		28	--			
		5 May			292 ± 7	
		11	--			
		22				384 ± 6
		26	324 ± 11			
		10 June			374 ± 11	
		15				427 ± 23
		7 July	428 ± 7		393 ± 13	
		15				436 ± 10
	Switchgrass	11 May	284 ± 12			
		20			338 ± 13	
		22		362 ± 13		
		29	359 ± 9			
		3 June			377 ± 20	389 ± 8
		17		392 ± 12		
		29	368 ± 8			
		1 July			387 ± 6	431 ± 11
		31				460 ± 19
		10 Aug.			396 ± 8	
11	356 ± 6	385 ± 5				
28				--		
Delayed	Tall fescue	15 June	340 ± 12			
		10 July			380 ± 10	
		13	353 ± 14			
		13 Aug.				414 ± 7
		24	299 ± 16		334 ± 7	
	11 Sep.				364 ± 7	
	Switchgrass	13 July	421 ± 13			
		21		430 ± 16	390 ± 15	
		13 Aug.				407 ± 10
		25				356 ± 12

† Means ± standard error of the mean.

Appendix Table 19. Acid detergent fiber (ADF) concentration of tall fescue and switchgrass under different harvest managements and intensities in 1988.

Harvest management	Species	Harvest date	Harvest intensity			
			Heavy	Medium	Light	Control
			ADF (g kg <sup>-1</sup> )			
Normal	Tall fescue	21 April	257 ± 3 †			
		3 May			299 ± 16	
		13	327 ± 4			
		22				--
		11 June	322 ± 4			
		13				--
		27			387 ± 8	
		2 July	363 ± 11			
		15				--
		27 May				--
	Switchgrass	31	254 ± 6			
		8 June			295 ± 3	
		10		299 ± 3		
		11				--
		27	321 ± 4		334 ± 6	--
		16 July		332 ± 2		
		7 Aug.	362 ± 4			
Delayed	Tall fescue	8			356 ± 3	
		16				--
		17		363 ± 5		
		27 June	338 ± 3			--
		16 July			381 ± 14	--
	Switchgrass	1 Aug.	336 ± 7			
		26				--
		1 Sep.	305 ± 5		326 ± 2	
		2 July	338 ± 9			--
		9		333 ± 2	327 ± 4	
		24				--
		9 Aug.			370 ± 2	
		13	359 ± 8			
		17		376 ± 5		
22				--		
13 Sep.				--		
28				--		

†Means ± standard error of the mean.

Appendix Table 20. Acid detergent lignin (ADL) concentration of tall fescue and switchgrass under different harvest managements and intensities in 1987.

Harvest management	Species	Harvest date	Harvest intensity			
			Heavy	Medium	Light	Control
			ADL (g kg <sup>-1</sup> )			
Normal	Tall fescue	18 April	11 ± 4			
		28	--			
		5 May			29 ± 2	
		11	--			
		22				52 ± 3
		26	41 ± 2			
		10 June			58 ± 8	
		15				71 ± 10
		7 July	51 ± 4		67 ± 10	
	15				73 ± 7	
	Switchgrass	11 May	58 ± 7			
		20			64 ± 11	
		22		63 ± 11		
		29	63 ± 8			
		3 June			66 ± 14	61 ± 7
		17		71 ± 12		
		29	62 ± 6			
		1 July			66 ± 9	70 ± 6
		31				80 ± 13
10 Aug.				67 ± 10		
11	60 ± 6	68 ± 5				
28				--		
Delayed	Tall fescue	15 June	61 ± 11			
		10 July			62 ± 8	
		13	62 ± 14			
		13 Aug.				91 ± 13
		24	48 ± 12		61 ± 2	
	11 Sep.				45 ± 5	
	Switchgrass	13 July	78 ± 13			
		21		67 ± 7	60 ± 6	
		13 Aug.				70 ± 10
25					58 ± 4	

† Means ± standard error of the mean.

Appendix Table 21. Acid detergent lignin (ADL) concentration of tall fescue and switchgrass under different harvest managements and intensities in 1988.

Harvest management	Species	Harvest date	Harvest intensity				
			Heavy	Medium	Light	Control	
			ADL (g kg <sup>-1</sup> )				
Normal	Tall fescue	21 April	20 ± 4				
		3 May			28 ± 8		
		13	31 ± 1				
		22				--	
		11 June	32 ± 7				
		13				--	
		27			44 ± 5		
	Switchgrass	2 July	54 ± 2				
			15			--	
		27 May	31	30 ± 2			--
			8 June			36 ± 1	
			10		33 ± 2		
			11				--
			27	39 ± 2		37 ± 3	--
			16 July		45 ± 2		
			7 Aug.	52 ± 2			
			8			50 ± 2	
Delayed	Tall fescue	27 June	37 ± 3			--	
		16 July			59 ± 7	--	
		1 Aug.	55 ± 2				
		26				--	
	Switchgrass	1 Sep.	39 ± 5		40 ± 3		
		2 July	47 ± 2			--	
		9		42 ± 2	44 ± 1		
		24				--	
		9 Aug.			51 ± 7		
		13	45 ± 4				
Switchgrass	17		46 ± 2				
	22				--		
	13 Sep.				--		
	28				--		

†Means ± standard error of the mean.

Appendix Table 22. Cellulose concentration of tall fescue and switchgrass under different harvest managements and intensities in 1987.

Harvest management	Species	Harvest date	Harvest intensity			
			Heavy	Medium	Light	Control
			Cellulose (g kg <sup>-1</sup> )			
Normal	Tall fescue	18 April	200 ± 2			
		28	--			
		5 May			263 ± 7	
		11	--			
		22				332 ± 6
		26	284 ± 10			
		10 June			315 ± 6	
		15				355 ± 13
		7 July	326 ± 1		326 ± 4	
		15				364 ± 5
	Switchgrass	11 May	226 ± 5			
		20			274 ± 4	
		22		299 ± 12		
		29	297 ± 4			
		3 June			312 ± 7	328 ± 6
		17		321 ± 6		
		29	307 ± 6			
		1 July			321 ± 6	361 ± 7
		31				379 ± 10
		10 Aug.			329 ± 10	
11	296 ± 2	316 ± 1				
28				--		
Delayed	Tall fescue	15 June	279 ± 1			
		10 July			318 ± 5	
		13	291 ± 2			
		13 Aug.				323 ± 6
		24	250 ± 9		273 ± 5	
	11 Sep.				319 ± 6	
	Switchgrass	13 July	342 ± 4			
		21		362 ± 9	330 ± 10	
		13 Aug.				337 ± 10
		25				--

† Means ± standard error of the mean.

Appendix Table 23. Cellulose concentration of tall fescue and switchgrass under different harvest managements and intensities in 1988.

Harvest management	Species	Harvest date	Harvest intensity			
			Heavy	Medium	Light	Control
			Cellulose (g kg <sup>-1</sup> )			
Normal	Tall fescue	21 April	237 ± 3			
		3 May			271 ± 8	
		13	296 ± 5			
		22				--
		11 June	290 ± 4			
		13				--
		27			343 ± 5	
	2 July	310 ± 10				
	15				--	
	Switchgrass	27 May				--
		31	224 ± 6			
		8 June			259 ± 2	
		10		266 ± 4		
		11				--
		27	281 ± 4		297 ± 4	--
		16 July		287 ± 3		
		7 Aug.	309 ± 3			
8				307 ± 2		
16					--	
17		314 ± 2				
Delayed	Tall fescue	27 June	302 ± 5			--
		16 July			322 ± 12	--
		1 Aug.	282 ± 5			
		26				--
		1 Sep.	266 ± 3		286 ± 2	
	Switchgrass	2 July	291 ± 7			--
		9		292 ± 2	284 ± 4	
		24				--
		9 Aug.			319 ± 2	
		13	314 ± 5			
		17		330 ± 4		
		22				--
		13 Sep.				--
28				--		

†Means ± standard error of the mean.

Appendix Table 24. Hemicellulose concentration of tall fescue and switchgrass under different harvest managements and intensities in 1987.

Harvest management	Species	Harvest date	Harvest intensity			
			Heavy	Medium	Light	Control
			Hemicellulose (g kg <sup>-1</sup> )			
Normal	Tall fescue	18 April	313 ± 6			
		28	--			
		5 May			261 ± 17	
		11	--			
		22				303 ± 20
		26	348 ± 12			
		10 June			328 ± 21	
		15				280 ± 12
		7 July	329 ± 3		357 ± 19	
	15				306 ± 10	
	Switchgrass	11 May	395 ± 2			
		20			404 ± 24	
		22		386 ± 9		
		29	406 ± 15			
		3 June			393 ± 18	351 ± 26
		17		357 ± 19		
		29	407 ± 13			
		1 July			372 ± 15	367 ± 18
		31				303 ± 14
10 Aug.				353 ± 8		
11	341 ± 14	337 ± 10				
28				--		
Delayed	Tall fescue	15 June	332 ± 16			
		10 July			330 ± 25	
		13	324 ± 16			
		13 Aug.				292 ± 24
		24	357 ± 19		326 ± 15	
	11 Sep.				322 ± 5	
	Switchgrass	13 July	381 ± 16			
		21		337 ± 20	363 ± 17	
		13 Aug.				324 ± 16
		25				384 ± 11

† Means ± standard error of the mean.

Appendix Table 25. Hemicellulose concentration of tall fescue and switchgrass under different harvest managements and intensities in 1988.

Harvest management	Species	Harvest date	Harvest intensity				
			Heavy	Medium	Light	Control	
			Hemicellulose (g kg <sup>-1</sup> )				
Normal	Tall fescue	21 April	301 ± 8				
		3 May			279 ± 21		
		13	316 ± 4				
		22				--	
		11 June	439 ± 19				
		13				--	
		27			315 ± 18		
	Switchgrass	2 July	377 ± 5				
			15			--	
		27 May	454 ± 5			--	
			8 June			449 ± 8	
			10		436 ± 18		
			11				--
			27	402 ± 18		411 ± 3	--
			16 July		442 ± 11		
			7 Aug.	432 ± 7			
			8			398 ± 9	
Delayed	Tall fescue	27 June	349 ± 22			--	
		16 July			381 ± 23	--	
		1 Aug.	387 ± 13				
		26				--	
	Switchgrass	1 Sep.	327 ± 8		326 ± 9		
		2 July	432 ± 7			--	
		9		402 ± 14	404 ± 8		
		24				--	
		9 Aug.			390 ± 6		
		13	351 ± 24				
	17	401 ± 15					
		22			--		
	13 Sep.				--		
	28				--		

†Means ± standard error of the mean.

Appendix Table 26. Specific leaf weight (SLW) of tall fescue and switchgrass under different harvest managements and intensities in 1987.

Harvest management	Species	Harvest date	Harvest intensity			
			Heavy	Medium	Light	Control
			SLW (g m <sup>-2</sup> )			
Normal	Tall fescue	18 April	46.0 ±3.0			46.0 ±3.0
		28	47.2 ±3.1			
		5 May			38.3 ±2.0	38.3 ±2.0
		11	39.9 ±2.2			
		22				50.7 ±3.2
		26	53.1 ±2.8			
		10 June			79.5 ±5.0	
		15				69.3 ±4.7
		7 July	60.3 ±3.3		55.5 ±4.2	
	Switchgrass	15				66.0 ±2.9
		11 May	49.4 ±1.4			49.4 ±1.4
		20			53.4 ±2.4	
		22		52.7 ±2.8		52.7 ±2.8
		29	49.6 ±2.6			
		3 June			45.5 ±2.7	55.9 ±0.5
		17		54.1 ±1.8		
		29	52.6 ±1.4			
		1 July			52.9 ±3.8	61.4 ±0.7
		31				78.8 ±3.9
Delayed	Tall fescue	10 Aug.			57.6 ±2.5	
		11	56.0 ±2.8	59.8 ±2.5		
		28				--
		15 June	70.3 ±7.7			70.3 ±7.7
		10 July			58.3 ±2.9	58.2 ±2.9
	Switchgrass	13	55.0 ±1.5			
		13 Aug.				54.5 ±6.4
		24	--		--	
		11 Sep.				72.1 ±9.2
		13 July	46.8 ±1.7			46.8 ±1.7
Switchgrass	21		58.7 ±2.7	52.4 ±2.5	58.7 ±2.7	
	13 Aug.				71.0 ±3.8	
	25				59.4 ±1.9	

† Means ± standard error of the mean.

Appendix Table 27. Specific leaf weight (SLW) of tall fescue and switchgrass under different harvest managements and intensities in 1988.

Harvest management	Species	Harvest date	Harvest intensity			
			Heavy	Medium	Light	Control
			SLW (g m <sup>-2</sup> )			
Normal	Tall fescue	21 April	43.7 ±1.5			--
		3 May			62.2 ±2.0	--
		13	53.8 ±3.6			
		22				--
		11 June	52.2 ±3.8			
		13				--
		27			87.0 ±4.7	
	Switchgrass	2 July	57.6 ±3.2			
		15				--
		27 May				--
		31	59.0 ±2.6			
		8 June			61.5 ±3.0	
		10		61.0 ±2.6		
		11				--
		27	68.3 ±3.3		66.7 ±1.5	--
		16 July		69.8 ±2.3		
		7 Aug.	52.8 ±3.7			
8			63.4 ±1.4			
16				--		
17		54.9 ±2.3				
Delayed	Tall fescue	27 June	84.9 ±5.4			--
		16 July			53.2 ±1.7	--
		1 Aug.	66.5 ±2.0			
		26				--
	Switchgrass	1 Sep.	--		--	
		2 July	71.9 ±2.5			--
		9		74.6 ±2.8	80.8 ±4.2	
		24				--
		9 Aug.			48.8 ±1.1	
		13	51.2 ±1.2			
		17		51.6 ±1.4		
		22				--
		13 Sep.				--
28				--		

†Means ± standard error of the mean.

Appendix Table 28. Leaf area index (LAI) of tall fescue and switchgrass under different harvest managements and intensities in 1987.

Harvest management	Species	Harvest date	Harvest intensity			
			Heavy	Medium	Light	Control
Normal	Tall fescue	18 April	0.3 ±0.1			0.3 ±0.2
		28	1.0 ±0.1			
		5 May			3.1 ±0.1	3.1 ±0.1
		11	1.3 ±0.1			
		22				2.3 ±0.4
		26	1.2 ±0.1			
		10 June			2.5 ±0.2	
		15				4.7 ±0.5
		7 July	1.2 ±0.1		1.0 ±0.1	
		15				4.4 ±0.3
	Switchgrass	11 May	0.7 ±0.1			0.7 ±0.1
		20			1.1 ±0.1	
		22		1.6 ±0.1		1.6 ±0.1
		29	2.3 ±0.1			
		3 June			1.8 ±0.3	4.2 ±0.4
		17		2.0 ±0.1		
		29	2.3 ±0.1			
		1 July			1.7 ±0.1	6.0 ±0.4
		31				4.8 ±0.3
		10 Aug.			1.4 ±0.1	
Delayed	Tall fescue	15 June	1.9 ±0.4			2.0 ±0.4
		10 July			4.7 ±0.2	4.7 ±0.2
		13	1.5 ±0.1			
		13 Aug.				3.8 ±0.4
		24	--		--	
	11 Sep.				3.7 ±0.4	
	Switchgrass	13 July	3.2 ±0.2			3.2 ±0.2
		21		4.1 ±0.1	5.0 ±0.1	4.1 ±0.1
		13 Aug.				4.1 ±0.3
		25				3.6 ±0.2
28					--	

† Means ± standard error of the mean.

Appendix Table 29. Leaf area index (LAI) of tall fescue and switchgrass under different harvest managements and intensities in 1988.

Harvest management	Species	Harvest date	Harvest intensity			
			Heavy	Medium	Light	Control
Normal	Tall fescue	21 April	1.0 ±0.1 †			--
		3 May			2.1 ±0.2	--
		13	1.9 ±0.2			--
		22				--
		11 June	1.0 ±0.1			--
		13				--
	Switchgrass	27 May				--
		31	1.9 ±0.4			--
		8 June			2.1 ±0.2	
		10		2.5 ±0.1		
		11				--
		27	1.0 ±0.1		1.0 ±0.1	--
		16 July		1.4 ±0.1		
		7 Aug.	2.1 ±0.2			
		8			1.3 ±0.1	
		16				--
		17		2.0 ±0.1		
		Delayed	Tall fescue	27 June	0.6 ±0.1	
16 July					1.0 ±0.1	--
1 Aug.	0.3 ±0.1					--
26						--
Switchgrass	1 Sep.		--		--	--
	2 July		1.1 ±0.1			--
	9			1.4 ±0.2	0.6 ±0.1	
	24					--
	9 Aug.				2.6 ±0.1	
	13		2.5 ±0.1			
	17			2.4 ±0.1		
	22					--
13 Sep.				--		
28				--		

†Means ± standard error of the mean.

Appendix Table 30. Coefficients of extinction (K) of tall fescue and switchgrass under different harvest managements and intensities in 1987.

Harvest management	Species	Harvest date	Harvest intensity			
			Heavy	Medium	Light	Control
Normal	Tall fescue	18 April	--			--
		28	0.4 ±0.05 †			
		5 May			0.3 ±0.01	0.3 ±0.01
		11	0.4 ±0.03			
		22				0.8 ±0.1
		26	0.4 ±0.06			
		10 June			0.4 ±0.04	
		15				0.4 ±0.01
		7 July	0.6 ±0.09		0.6 ±0.07	
		15				0.6 ±0.03
	Switchgrass	11 May	0.7 ±0.08			0.7 ±0.08
		20			0.5 ±0.03	
		22		0.6 ±0.06		0.6 ±0.06
		29	0.5 ±0.04			
		3 June			0.5 ±0.1	0.4 ±0.05
		17		0.4 ±0.04		
		29	0.4 ±0.03			
		1 July			0.6 ±0.03	0.4 ±0.01
		31				0.5 ±0.04
		10 Aug.			0.5 ±0.04	
Delayed	Tall fescue	15 June	0.3 ±0.05			0.3 ±0.05
		10 July			0.4 ±0.02	0.4 ±0.02
		13	1.1 ±0.06			
		13 Aug.				0.4 ±0.04
		24	--		--	
	11 Sep.				0.4 ±0.03	
	Switchgrass	13 July	0.5 ±0.03			0.5 ±0.03
		21		0.5 ±0.01	0.3 ±0.01	0.5 ±0.01
		13 Aug.				--
		25				0.5 ±0.03

† Means ± standard error of the mean.

Appendix Table 31. Coefficients of extinction (K) of tall fescue and switchgrass under different harvest managements and intensities in 1988.

Harvest management	Species	Harvest date	Harvest intensity			
			Heavy	Medium	Light	Control
			K			
Normal	Tall fescue	21 April	0.5 ±0.05 †			--
		3 May			0.5 ±0.06	--
		13	0.5 ±0.06			
		22				--
		11 June	0.9 ±0.1			
		13				--
		27			1.0 ±0.1	
		2 July	1.5 ±0.3			
		15				--
	Switchgrass	27 May				--
		31	0.7 ±0.1			
		8 June			0.8 ±0.09	
		10		0.3 ±0.05		
		11				--
		27	1.2 ±0.08		1.8 ±0.1	--
		16 July		0.7 ±0.03		
		7 Aug.	0.6 ±0.06			
		8			0.8 ±0.08	
Delayed	Tall fescue	27 June	0.7 ±0.1			--
		16 July			0.7 ±0.1	--
		1 Aug.	1.9 ±0.3			
		26				--
		1 Sep.	--		--	
		Switchgrass	2 July	0.4 ±0.03		
	9			0.5 ±0.07	1.2 ±0.03	
	24					--
	9 Aug.				0.5 ±0.02	
	13		0.5 ±0.02			
	17			0.7 ±0.05		
	22					--
	13 Sep.					--
	28					--

†Means ± standard error of the mean.

## VITA

Dale Warren Ball was born July 8, 1957 in Richmond, Virginia. He was raised in the city of Richmond. He graduated from George Wythe High School in Richmond, Virginia in 1975.

The author enrolled at Virginia Polytechnic Institute and State University in September of 1975. After two years in the Animal Science curriculum Dale left school to manage a commercial swine farm in Bailey, North Carolina. After four years, the author accepted a job as a herdsman on a dairy farm in Mount Airy, North Carolina. The author accepted a job as seed manager for Longest Seed Company in August 1982. In August 1984, the author returned to Virginia Polytechnic Institute and State University and received a Bachelor of Science in Agronomy and a minor in Animal Science in June 1987. The author has pursued a Master of Science in Agronomy until now. The author accepted a research associate position in Agronomy Extension in August 1989 and is planning to pursue a Doctor of Philosophy degree in Crop and Soil Environmental Sciences.

The author is a member of the American Society of Agronomy, Crop Science Society of America, American Forage and Grassland Council, Virginia Forage and Grassland Council, and the Virginia Corn Growers Association.

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