10-1981

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RESEARCH REPORT 70, OCTOBER 1981

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The research reported in this publication was supported in part by Federal funds made available through the provisions of the Hatch Act.

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Received for publication August 12, 1981

NUTRITIVE EVALUATION OF INDIGENOUS WARM-SEASON GRASSES IN CONNECTICUT

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Warm-season perennial grasses are not important as sources of pasture or hay for the Connecticut animal industry. However, several warm-season grasses naturally occur on infertile and poorly managed areas within this state. The growth pattern of these grasses suggests that they may be a perennial source of summer forage which, frequently, is not always available in adequate quantities. Utilization of such grasses for summer forage has been suggested in Pennsylvania (Jung et al., 1978).

Four warm-season grasses commonly found in Connecticut are big bluestem (Andropogon gerardi Vitman), little bluestem (Andropogon scoparius Michx.), switchgrass (Panicum virgatum L.), and indiangrass (Sorghastrum nutans (L.) Nash). All four species are perennials, are widely distributed throughout the United States, and begin growth late in the spring continuing throughout the summer. While considerable information is available on these and other comparable native species, such information has largely been gathered in areas other than the northeastern United States. Therefore, native populations of these four warm-season grasses were selected and samples collected with the following objectives: (1) to determine quality and mineral characteristics throughout the growing season, (2) to evaluate the potential usefulness

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of the warm-season grasses for providing summer and fall forage, and (3) to examine the influence of leaf and stem fractions on whole plant quality and mineral constituents.

MATERIALS AND METHODS

1977 Warm-Season Grass Survey

Samples of four uncultivated, warm-season grasses were collected at approximately weekly intervals from mid-June until November 1, 1977. Big bluestem and indiangrass were collected in Coventry, Connecticut at a site located 50-75 m eastnortheast of the junction of Rt. 44A and Rt. 31. Switchgrass and little bluestem were collected in Tolland, Connecticut at a site along the exit ramp of I-86 westbound and 10-30 m from Rt. 195. Samples were collected by clipping plants at a 4-6 cm height and removing all of the previous year's growth. At the time of collection average plant height, average third or fourth leaf width, approximate growth stage, and sample wet weight were recorded.

Plant samples were dried at 60 C and then weighed. Dried samples were ground in a Wiley mill to pass a 1-mm stainless steel screen and stored in sealed plastic bags until quality and mineral analyses were performed.

Samples were analyzed for <u>in vitro</u> dry matter digestibility (IVDMD) using the modified procedure of Tilley and Terry (1963). Cell wall constituents (CWC) were determined using the procedure of Van Soest and Wine (1967). Acid - detergent fiber (ADF) and acid - detergent lignin (ADL) were determined using the method of Van Soest (1963). Nitrogen was determined using the macro-Kjeldahl method of Bremner (1965). Samples

for mineral analyses were digested in nitric and perchloric acids (Hagstrom and Rubins, 1961). Digestates were analyzed for mineral concentration using atomic absorption spectrophotométry on a Perkin-Elmer 403 atomic absorption spectrophotometer. Phosphorus in the digestate was determined by colorimetry using the molybdophosphoric blue colorimetric method (Dickman and Bray, 1940).

Soil samples were taken at the collection sites. Soil extracts were made using a NH_4OAc (pH 4.8) extractant for calcium, phosphorus, magnesium, and potassium determinations (McIntosh, 1969). A DTPA extractant was used for other mineral analyses. Phosphorus in the extracts was determined using the technique of Dickman and Bray (1940). Potassium and calcium were determined using flame photometry. All other minerals were determined using atomic absorption spectrophotometry. Soil pH was determined using a soil:water (1:1) paste.

1978 Warm-Season Grass Survey

Samples of big bluestem and indiangrass were collected in 1978 from September 13 until November 1 on the same dates used in 1977. The grasses were collected from the Coventry, Connecticut site used in 1977. Samples were collected by clipping plants at a 4-6 cm height and removing all of the previous year's growth. A sample of the entire plant was collected and another sample was separated into leaf blades (leaf blade including any portion of the leaf sheath not attached to the stem) and stem (the inflorescence culm plus attached leaf sheaths). Samples were dried, ground and analyzed as described previously.

RESULTS AND DISCUSSION

1977 Survey

Soil Test Results

The soil fertility at the collection sites was quite low (Table 1). Soil pH ranged from 5.0 to 5.6. Soil calcium, magnesium, and potassium levels were lowest at the little bluestem and switchgrass sites. All values for calcium, magnesium, and phosphorus were very low when compared to values usually found for maintained agricultural soils. Of the heavy trace elements, extractable lead was found to be very high especially at the switchgrass site. Soil lead values for all sites were higher than values reported for Connecticut alfalfa soils (Taylor, 1974).

Plant Development

The stage of maturity for the four warm-season grasses during the collection period is shown in Table 2. Jointing in switchgrass began during mid- to late-June but jointing in the other species did not begin until the middle of July. Switchgrass was found to reach anthesis approximately one month before any of the other warm-season grasses. This is in agreement with the observation of Dwyer and Elder (1964) and Gilbert (1976). Big bluestem, little bluestem, and indiangrass reached anthesis during mid-August. Seed dispersal in switchgrass began before frost but the seed dispersal of the other grasses had only just begun by frost.

Table 1. Soil test values from the sites where the warm-season grasses were collected in 1977 and 1978.

Site by species	Soil component*												
	Ca	Mg	P	K	Cu	Zn	Fe	Mn	Cd	Ni	Pb	Al	pH
	kg/ha												
Big bluestem	400	35	1	165	9	30	145	40	0.26	2.1	139	211	5.3
Little bluestem	50	10	1	80	4	8	112	58	0.16	2.0	91	348	5.0
Switchgrass	100	20	2	60	6	19	152	16	0.16	2.4	294	132	5.6
Indiangrass	600	40	1	160	9	22	129	46	0.36	2.3	190	234	5.5

*Ca, Mg, P, and K measured using NH_4OAc(pH 4.8) extractant. Other elements measured using DTPA extractant.

By the end of the growing season big bluestem was 20 to 25 cm taller than indiangrass and switchgrass, respectively, and 60 cm taller than little bluestem (Table 2). This finding contradicts the findings of Dwyer and Hutcheson (1965) for these warm-season grasses in northcentral Oklahoma. They found that switchgrass was taller than big bluestem and indiangrass but big bluestem was about the same height as little bluestem. Plant height again revealed the early development of the switchgrass when compared to the other warm-season grasses.

Increasing maturity had no effect on leaf blade width (Table 2). For most harvest dates switchgrass and indiangrass leaf blades were wider than big and little bluestem. Little bluestem had the narrowest leaf blades of the four warm-season grasses studied. These findings were similar to the findings of Dwyer and Hutcheson (1965).

Dry Matter Accumulation

The early maturation of switchgrass was evident in the pattern of dry matter accumulation (Table 3). Dry matter accumulation occurred rapidly in June and early July so that during July switchgrass contained about 40% dry matter. Big bluestem contained approximately 20-22% dry matter during the first three weeks of June, but from the end of June until the middle of August, the dry matter content was slightly less than 30% (Table 3). This is in agreement with Hobbs, Gallup, and Taylor (1945) who found in Oklahoma that for a native pasture, predominately bluestem, the dry matter of the grass varied from 32.7 to 39.0% from late in May until the middle of September. The dry matter content of little bluestem

Table 2. Stage of maturity, plant height, and leaf blade width of four warm-season grasses sampled from 14 June to 1 November, 1977.

1977 harvest date	Big bluestem			Little bluestem			Switchgrass			Indiangrass		
	Maturity stage	Ht	Wth	Maturity stage	Ht	Wth	Maturity stage	Ht	Wth	Maturity stage	Ht	Wth
		-cm-	-mm-		-cm-	-mm-		-cm-	-mm-		-cm-	-mm-
14 - 6	5 leaves	60	11	3 leaves	30	5	5 leaves	65	13	3 leaves	60	12
21 - 6	6 leaves	60	9	3 leaves	45	4	Jointing	80	13	4 leaves	55	11
27 - 6	6 leaves	60	9	5 leaves	40	4	Jointing	100	13	4 leaves	60	12
1 - 7	6-7 leaves	70	7	5 leaves	55	5	20% heading	120	14	4 leaves	60	13
11 - 7	7-8 leaves	80	7	6 leaves	45	4	80% heading	110	14	Jointing	70	12
19 - 7	Jointing	85	8	Jointing	60	4	20% anthesis	140	13	Jointing	80	14
26 - 7	Jointing	90	10	Jointing	70	5	30% anthesis	130	14	Jointing	85	13
1 - 8	Jointing	90	9	50% heading	80	7	80% anthesis	140	15	10% heading	90	14
9 - 8	10% heading	100	9	80% heading	90	5	100% anthesis	150	15	40% heading	100	13
17 - 8	50% heading	120	8	100% heading	95	6	Seed set	160	13	10% anthesis	160	13
23 - 8	20% anthesis	140	8	20% anthesis	90	6	Seed set	155	13	20% anthesis	165	13
30 - 8	50% anthesis	160	8	40% anthesis	90	6	Seed set	155	14	50% anthesis	160	13
6 - 9	100% anthesis	175	16	80% anthesis	95	5	Seed set	150	15	100% anthesis	160	14
13 - 9	Seed set	175	11	100% anthesis	115	6	Seed set	150	13	Seed set	155	11
21 - 9	Seed set	NC*	LS**	Seed set	NC	LS	Seed drop	NC	LS	Seed set	NC	LS
27 - 9	Seed set	NC	LS	Seed set	NC	LS	Seed drop	NC	LS	Seed set	NC	LS
4 - 10	Seed set	NC	LS	Seed set	NC	LS	Seed drop	NC	LS	Seed set	NC	LS
10 - 10	Seed drop	NC	LS	Seed drop	NC	LS	Seed drop	NC	LS	Seed drop	NC	LS
1 - 11	Seed drop	NC	LS	Seed drop	NC	LS	Seed drop	NC	LS	Seed drop	NC	LS

*No change, ** Leaf senescence.

fluctuated considerably throughout the June to August period when the percentage dry matter ranged from 23.9 to 40.8%. Dry matter accumulation was rapid for little bluestem during September and October. After 21 June, the dry matter content of indiangrass remained about 30% until late August when the dry matter increased to about 40%. The dry matter percentage of indiangrass almost doubled between 10 October and 1 November, increasing from 43.3 to 81.8%.

Dry matter values reported herein during June to September were below the values reported for all four warm-season grasses in Central Oklahoma by Waller et al. (1972). Values for October and November were similar to those of Waller et al. (1972).

Quality, Fiber, and Mineral Components

Increasing maturity had a marked effect on the IVDMD of all four grasses (Table 3). Indiangrass generally was higher in IVDMD than the other warm-season grasses. Big bluestem was higher in IVDMD than switchgrass and switchgrass was higher than little bluestem on most harvest dates.

After 27 June, switchgrass showed a steady decline in IVDMD, particularly during inflorescence emergence. After anthesis, IVDMD remained relatively constant at around 35 to 40% until fall. The IVDMD of big bluestem declined with increasing maturity although the variability from harvest date to harvest date was greater for big bluestem than for the other grasses. Little bluestem showed the least reduction

Table 3. Percent dry matter, IVDMD, and crude protein in big bluestem (BBS), little bluestem (LB), switchgrass (SG), and indiangrass (IG) as affected by increasing maturity (1977).

1977 harvest dates	IVDMD				Dry matter				Crude protein			
	BBS	LBS	SG	IG	BBS	LBS	SG	IG	BBS	LBS	SG	IG
	%											
14 - 6	64.9	44.2	57.1	63.8	19.8	25.9	31.9	21.7	13.39	9.97	13.41	12.00
21 - 6	44.0	43.8	46.6	58.6	22.4	23.9	26.6	28.4	9.52	9.55	10.35	10.08
27 - 6	57.4	49.0	55.7	65.0	28.4	34.6	29.3	30.7	9.26	6.67	10.31	8.74
1 - 7	52.0	47.6	49.8	60.1	26.4	27.2	26.7	32.9	9.58	8.35	7.37	10.03
11 - 7	48.1	41.2	42.9	58.1	27.1	32.6	35.2	30.5	8.33	5.81	6.64	9.47
19 - 7	45.0	42.2	43.2	57.6	28.4	40.8	46.2	28.4	7.18	6.00	5.65	8.71
26 - 7	47.1	39.3	38.7	59.5	28.1	34.0	36.7	30.1	7.00	7.02	5.46	9.68
1 - 8	48.2	39.5	39.6	54.9	25.0	33.8	46.4	26.8	7.91	5.54	5.19	8.82
9 - 8	47.0	38.5	39.4	53.1	28.0	39.7	40.7	29.9	5.30	4.56	5.32	8.31
17 - 8	38.0	35.4	35.6	44.9	29.7	36.0	40.2	31.6	7.42	4.99	4.85	7.22
23 - 8	41.4	33.9	36.4	44.4	38.7	32.0	38.8	38.3	5.43	5.46	5.21	5.25
30 - 8	32.5	27.3	37.0	50.9	38.0	33.4	37.0	35.0	4.39	3.56	4.85	5.50
6 - 9	38.1	32.4	36.8	43.6	39.0	34.2	35.1	34.8	4.08	4.25	4.72	5.09
13 - 9	34.7	27.0	36.5	41.0	43.6	45.7	45.8	39.7	4.80	4.60	5.13	5.41
21 - 9	32.3	27.4	34.5	34.5	45.2	45.5	45.6	39.5	3.47	4.57	3.78	4.70
27 - 9	35.6	31.7	28.4	30.4	42.9	59.4	46.5	39.3	3.93	2.89	3.77	3.87
4 - 10	22.4	27.4	28.7	36.4	55.6	66.2	52.7	47.4	1.80	3.27	2.88	2.89
10 - 10	24.8	26.8	21.9	30.5	56.7	55.1	57.1	43.3	1.83	2.98	2.78	2.18
1 - 11	23.2	24.3	23.4	23.8	76.3	75.4	81.9	81.8	1.98	2.21	2.76	2.00
Mean	40.9	35.7	38.5	48.0	36.8	40.8	42.1	36.3	6.14	5.38	5.81	6.84
SD*	11.4	7.8	9.5	12.5	14.2	14.0	12.7	12.7	3.11	2.18	2.81	2.97
CV**	27.8	21.8	24.6	26.1	38.7	34.3	30.2	34.9	50.66	40.47	48.28	43.48

* Standard deviation

** Coefficient of variation

in IVDMD during maturation and subsequent weathering during the fall, but little bluestem did have the lowest IVDMD values throughout the collection period. Indiangrass IVDMD declined more slowly than the other warm-season grasses, consistently remaining above 50% until August. The IVDMD of switchgrass, big bluestem, and indiangrass declined rapidly with inflorescence emergence, levelled off until mid-September, and then further declined, probably as the result of weathering of the mature forage. Care, however, should be exercised in the interpretation of IVDMD data of warm-season grasses since IVDMD estimates may underestimate in vivo values (Griffin et al., 1980).

The warm-season grasses contained from 10.0 to 13.4% crude protein in mid-June and declined rapidly with increasing maturity (Table 3). This is in agreement with a report on the crude protein concentration of big and little bluestem by Whitman et al. (1951). On the average, crude protein concentration decreased 0.08 percentage points/day for big bluestem and switchgrass, 0.07 percentage points/day for indiangrass, and 0.06 percentage points/day for little bluestem. Perry and Baltensperger (1979) reported 0.07 and 0.05 percentage points/day decreases for the crude protein concentration of big bluestem and switchgrass leaves, respectively. Griffin (1979) found a decline of 0.03 percentage points/day for the crude protein concentration of big bluestem leaves.

Cell wall constituents (CWC) approached 80% for all grasses by the end of the growing season, (Table 4). Switchgrass showed little variation in CWC between 21 June and 21 September. Big bluestem was generally lower in CWC than the other warm-season grasses until after 17 August when the CWC began to increase until October. Indiangrass showed a slight increase in CWC throughout the growing season and a more rapid increase in CWC in

October. Little bluestem CWC were generally higher than the other warm-season grasses until after 21 September. Little bluestem did not exhibit the typical pronounced pattern of increasing CWC with maturity.

For all grasses the acid-detergent fiber (ADF) concentration generally increased throughout the growing season, though less so for little bluestem than the other species. Switchgrass had the lowest ADF concentration in mid-June but the concentration increased substantially during the jointing growth phase. The ADF concentrations of the four species were relatively similar during the late - July through the late - September period. Switchgrass tended to be slightly lower in ADF concentrations compared to the other grasses.

After an initial decrease in acid-detergent lignin (ADL) concentration in June, all grasses showed a marked effect of stage of development on ADL concentration (Table 4). During July, the ADL concentration of big and little bluestem was generally constant but increased rapidly during August and September. During July and August, switchgrass contained the greatest amount of ADL relative to the other grasses. The ADL concentration in switchgrass continued to increase throughout the growing season. Fall lignin concentrations of switchgrass were within the range reported by Kneebone et al. (1961), although the values were at the low end of the range. Indiangrass was generally lowest in ADL concentration.

Calcium concentrations, particularly for little bluestem, switchgrass, and indiangrass, varied considerably throughout the season (Table 5). The calcium concentrations of big and little bluestem were

Table 4. Percent cell wall constituents, (CWC), acid-detergent fiber, (ADF), and acid-detergent lignin (ADL) in big bluestem (BBS), little bluestem (LB), switchgrass (SG), and indiangrass (IG) as affected by increasing maturity (1977).

1977 harvest date	CWC				ADF				ADL			
	BBS	LBS	SG	IG	BBS	LBS	SG	IG	BBS	LBS	SG	IG
	%											
14 - 6	63.2	76.9	61.1	68.6	35.0	42.0	27.1	37.1	4.6	5.1	3.9	4.0
21 - 6	68.7	74.6	70.6	73.1	40.0	49.9	32.7	36.2	4.4†	5.7	4.0	4.0
27 - 6	65.4	76.4	66.2	69.7	34.6	37.6	36.0	35.7	4.1	4.0	3.9	3.2
1 - 7	65.0	76.0	70.3	68.8	35.5	40.4	39.1	36.4	4.6	4.8	4.5	3.5
11 - 7	67.1	76.2	69.1	69.0	37.5	42.1	37.0	37.7	4.7	4.6	5.1	3.4
19 - 7	69.2	74.4	67.9	71.8	38.2	40.8	36.3	40.1	5.1	4.5	5.2	4.0
26 - 7	69.8	71.3	70.8	70.7	39.4	40.8	41.2	40.6	5.2	5.4	5.7	4.3
1 - 8	69.4	74.8	69.9	71.5	37.9	40.6	40.8	42.0	4.4	4.2	5.8	5.0
9 - 8	73.4	73.7	69.7	70.7	43.4	42.8	39.6	41.3	3.4	5.2	6.1	4.5
17 - 8	67.6	73.4	71.5	73.1	40.3	43.0	41.8	43.0	5.3	6.0	6.5	5.2
23 - 8	74.2	72.1	69.8	75.3	45.3	42.5	38.1	45.0	6.8	6.5	6.6	5.5
30 - 8	73.9	75.2	68.3	74.8	43.4	42.7	40.7	44.1	6.9	6.0	7.7	6.5
6 - 9	72.4	75.2	69.9	72.2	44.5	44.6	41.7	45.6	6.4	5.8	6.7	6.5
13 - 9	73.8	75.5	68.3	72.5	44.7	46.2	41.4	44.7	6.9	7.5	6.9	6.1
21 - 9	75.5	75.4	70.2	72.6	48.1	45.2	40.7	45.0	7.7	7.0	7.1	5.9
27 - 9	75.4	79.3	79.4	77.2	47.9	48.6	47.7	48.3	7.0	6.9	8.1	6.4
4 - 10	80.2	75.8	77.0	74.0	51.7	46.7	46.8	45.8	10.0	8.2	8.7	6.6
10 - 10	80.4	77.9	78.3	78.3	51.7	48.4	47.6	52.7	9.6	7.2	8.1	6.7
1 - 11	79.4	79.2	77.0	79.7	54.0	48.1	47.8	51.2	9.8	6.9	8.7	6.8
Mean	71.8	75.4	70.8	72.8	42.8	43.8	40.2	42.8	6.2	5.9	6.3	5.2
SD*	5.1	2.1	4.4	3.2	5.9	3.4	5.3	4.9	2.0	1.2	1.6	1.3
CV**	7.1	2.7	6.2	4.3	13.8	7.7	13.1	11.6	32.6	20.4	25.1	24.5

* Standard deviation

** Coefficient of variation

† Lignin value corrected for heat artifact lignin (Van Soest, 1965).

similar to those reported by Waller et al. (1972) and were within the ranges reported by Daniel and Harper (1934). The calcium concentrations of switchgrass and indiangrass were, before September, below the levels reported by Waller et al. (1972).

Magnesium concentrations of all of the grasses were low and varied throughout the season. There was a tendency for the magnesium concentrations to decline with advancing maturity. The magnesium concentrations of switchgrass were typically below the levels reported by Balasko and Smith (1971).

Phosphorus concentrations generally declined with increasing plant development (Table 5). Whitman et al. (1951) reported higher values for the phosphorus concentrations of big bluestem although the concentrations observed for big and little bluestem were within the ranges reported by Daniel and Harper (1934). Before August, the phosphorus concentrations of the four grasses were above the concentrations reported by Waller et al. (1972) and the mean phosphorus concentration of the four species was greater than that reported by Briggs et al. (1948). After August the values were similar to those reported by Waller et al. (1972).

The potassium concentrations of the four species were clearly influenced by plant maturity, declining throughout the season. Little bluestem was consistently lower in potassium concentration than the other grasses.

The copper, iron, manganese, and zinc concentrations of the four grasses are shown in Table 6. Switchgrass had the greatest mean copper concentration relative to the other species. Over the 1972-73 period, Taylor and Allinson (1979) reported a range of copper concentrations of

Table 5. Percent calcium, magnesium, phosphorus, and potassium in big bluestem (BBS), little bluestem (LBS), switchgrass (SG), and indiangrass (IG) as affected by increasing maturity (1977).

1977 harvest date	Ca				Mg				P				K			
	BBS	LBS	SG	IG	BBS	LBS	SG	IG	BBS	LBS	SG	IG	BBS	LBS	SG	IG
	%															
14 - 6	0.23	0.32	0.10	0.21	0.09	0.07	0.04	0.07	0.29	0.20	0.23	0.29	2.64	1.24	1.57	2.30
21 - 6	0.23	0.27	0.21	0.22	0.06	0.09	0.11	0.06	0.19	0.20	0.18	0.23	1.91	1.67	1.38	1.90
27 - 6	0.21	0.30	0.20	0.15	0.06	0.05	0.20	0.11	0.18	0.13	0.20	0.23	1.71	1.22	1.23	1.86
1 - 7	0.23	0.30	0.13	0.34	0.06	0.11	0.07	0.09	0.19	0.18	0.26	0.16	1.66	1.44	1.81	1.51
11 - 7	0.23	0.37	0.13	0.38	0.06	0.07	0.06	0.09	0.20	0.12	0.23	0.15	1.60	1.14	1.48	1.33
19 - 7	0.21	0.43	0.10	0.18	0.06	0.12	0.05	0.08	0.18	0.12	0.19	0.30	1.41	0.91	1.32	1.92
26 - 7	0.24	0.46	0.17	0.15	0.09	0.09	0.05	0.10	0.17	0.14	0.17	0.27	1.18	1.05	1.13	1.57
1 - 8	0.26	0.48	0.17	0.22	0.08	0.06	0.06	0.11	0.18	0.11	0.16	0.27	1.24	1.08	1.19	1.57
9 - 8	0.23	0.46	0.20	0.22	0.06	0.09	0.06	0.16	0.16	0.09	0.19	0.25	1.18	0.71	0.94	1.43
17 - 8	0.26	0.47	0.17	0.24	0.07	0.10	0.05	0.10	0.18	0.09	0.18	0.21	1.08	0.69	1.04	1.31
23 - 8	0.26	0.47	0.18	0.15	0.07	0.12	0.06	0.07	0.15	0.09	0.17	0.17	0.84	0.64	0.81	1.23
30 - 8	0.29	0.44	0.21	0.25	0.08	0.11	0.06	0.06	0.12	0.08	0.17	0.19	0.80	0.65	0.76	1.05
6 - 9	0.32	0.41	0.26	0.43	0.06	0.10	0.06	0.06	0.09	0.08	0.17	0.16	0.66	0.64	0.74	0.91
13 - 9	0.27	0.40	0.29	0.40	0.06	0.09	0.07	0.08	0.11	0.09	0.17	0.14	0.72	0.56	0.76	0.91
21 - 9	0.24	0.27	0.23	0.45	0.04	0.09	0.06	0.05	0.08	0.10	0.14	0.14	0.66	0.37	0.76	0.86
27 - 9	0.24	0.17	0.26	0.41	0.04	0.05	0.05	0.04	0.09	0.06	0.11	0.11	0.70	0.31	0.74	0.76
4 - 10	0.24	0.27	0.30	0.36	0.03	0.06	0.07	0.04	0.08	0.07	0.10	0.14	0.47	0.28	0.65	0.66
10 - 10	0.26	0.23	0.30	0.19	0.03	0.04	0.06	0.03	0.07	0.09	0.08	0.10	0.32	0.31	0.45	0.69
1 - 11	0.32	0.23	0.22	0.12	0.02	0.04	0.03	0.03	0.06	0.07	0.06	0.05	0.29	0.12	0.16	0.41
Mean	0.25	0.36	0.20	0.27	0.06	0.08	0.07	0.08	0.15	0.11	0.17	0.19	1.11	0.79	1.00	1.27
SD*	0.03	0.10	0.06	0.11	0.02	0.03	0.04	0.03	0.06	0.04	0.05	0.07	0.61	0.43	0.41	0.51
CV**	13.52	27.89	30.86	40.67	33.40	31.98	53.72	43.48	40.60	38.07	30.61	37.18	54.61	54.56	41.29	40.08

* Standard deviation

** Coefficient of variation

1.6 - 29.3 ppm for alfalfa (Medicago sativa L.) in Connecticut. The copper concentrations for the warm season grasses were within this range. The iron concentrations of the four species varied considerably during the growing season with switchgrass having the greatest mean iron concentration. There was a tendency for the grasses to be lowest in iron concentration during the summer period. Little bluestem was higher in manganese concentration than the other grasses. During mid - June the manganese concentration of little bluestem was approximately 400 ppm and remained above 130 ppm until after September 21. There was a tendency, particularly with big and little bluestem and switchgrass, for zinc concentrations to increase through the summer and fall. The zinc concentrations in alfalfa, reported by Taylor and Allinson (1979), had a range of 16.6 - 52.3 ppm. Consequently, the zinc concentrations of the warm - season grasses, particularly in the summer - fall period, were typically greater than those observed for alfalfa.

Correlation coefficients for several selected comparisons are shown in Table 7 for big and little bluestem and in Table 8 for switchgrass and indiangrass. Since pairings were made on the basis of sampling dates, the stage of maturity of the grasses has a major influence on the coefficient values. Typically, for all grasses, dry matter concentrations were negatively and significantly correlated with both IVDMD and crude protein concentrations and positively and significantly correlated with CWC, ADF, and ADL concentrations. For all four species, crude protein and IVDMD concentrations were positively and significantly correlated. With the exception of little bluestem, the warm season grasses

Table 6. Percent copper, iron, manganese, and zinc in big bluestem (BBS), little bluestem (LBS), switchgrass (SG), and indiangrass (IG) as affected by increasing maturity (1977).

1977 harvest date	Cu				Fe				Mn				Zn			
	BBS	LBS	SG	IG	BBS	LBS	SG	IG	BBS	LBS	SG	IG	BBS	LBS	SG	IG
	ppm															
14 - 6	17.2	10.9	15.3	13.2	130	119	102	113	192	394	65	124	53	32	42	55
21 - 6	20.8	14.7	20.9	20.1	139	110	85	218	59	416	52	97	31	36	38	47
27 - 6	13.8	10.7	17.0	12.8	112	93	81	96	62	269	85	65	25	24	63	37
1 - 7	13.8	11.2	13.7	8.6	109	58	74	68	51	249	69	91	24	43	43	22
11 - 7	13.7	8.0	13.7	12.2	91	76	256	67	64	147	43	83	28	18	35	29
19 - 7	11.0	8.4	11.5	15.3	79	53	79	90	66	138	43	76	37	23	39	90
26 - 7	11.5	10.0	13.6	13.8	99	64	67	73	58	223	69	70	42	32	42	106
1 - 8	11.5	9.0	13.5	13.8	111	73	93	95	73	162	55	74	47	22	42	95
9 - 8	13.4	7.4	13.6	13.8	134	73	103	95	64	141	95	70	51	21	50	84
17 - 8	10.5	8.0	17.8	15.8	100	88	96	88	70	151	67	71	43	23	54	90
23 - 8	9.8	8.6	16.9	12.6	80	95	83	70	71	159	78	73	58	27	62	95
30 - 8	8.6	8.3	17.1	15.9	71	115	95	100	66	147	80	55	62	28	65	89
6 - 9	7.2	7.9	17.3	10.6	59	141	111	57	55	141	82	81	66	26	68	69
13 - 9	9.5	13.7	20.6	11.1	73	153	170	73	47	147	98	88	120	93	81	77
21 - 9	9.3	11.5	16.8	10.5	65	152	222	66	39	138	25	93	163	62	61	84
27 - 9	9.4	10.4	18.7	13.7	66	104	141	56	46	64	18	87	132	36	78	84
4 - 10	10.4	14.6	21.1	13.7	151	66	217	105	40	89	29	88	132	44	118	148
10 - 10	10.5	13.7	21.3	13.8	96	200	261	134	38	33	27	75	105	72	113	210
1 - 11	11.5	13.7	18.0	13.6	119	314	289	88	41	47	24	103	154	82	80	88
Mean	11.8	10.6	16.8	13.4	99	113	138	92	63	171	58	82	72	39	62	84
SD*	3.2	2.5	3.0	2.4	27.3	62.0	73.3	36.5	33.2	101.9	25.5	15.6	46.2	22.1	24.0	42.4
CV**	27.1	23.5	17.6	18.3	27.6	54.8	53.1	39.6	52.5	59.5	43.8	19.0	64.0	56.4	38.8	50.4

*Standard deviation
**Coefficient of variation

exhibited negative and significant correlations between IVDMD and either CWC, ADF, or ADL and between crude protein and either CWC, ADF or ADL. These relationships are similar to those that are typically observed in cool - season grasses. The absence of such consistent relationships with little bluestem is, at least in part, explained by the relatively limited changes that occurred in the structural components of this grass over the sampling period (Table 4). The coefficients of variation for CWC, ADF, and ADL in the case of little bluestem were substantially less than those observed for the other species.

Correlation coefficients between minerals and quality or fiber components again reflected the over-riding influence of maturity. Typically, where changes in specific minerals occurred as a consequence of plant maturity, significant correlations occurred between such specific mineral concentrations and either quality or fiber components. This was particularly the case for phosphorus, potassium, and zinc.

1978 Survey

Quality and Fiber Components

The leaf blades of big bluestem and indiangrass were higher in in vitro dry matter digestibility (IVDMD) than stems (Table 9). The IVDMD of the leaf blades of both species was relatively stable through September, after which IVDMD declined about 12 percentage points. Whole plant IVDMD declined throughout the collection period for both grasses. Decreases in IVDMD of the whole plant during the fall appeared to be caused primarily by a decline in the leaf IVDMD. As was the

Table 7. Correlation coefficients among selected comparisons of dry matter, IVDMD, crude protein, cell wall constituents, acid - detergent fiber and lignin, and several minerals for big and little bluestem.

	IVDMD	CP†	CWC	ADF	ADL	Ca	Mg	P	K	Cu	Fe	Mn	Zn
						Big bluestem							
DM‡	-0.86**	-0.85**	0.87**	0.92**	0.93**	0.59*	-0.80**	-0.86**	-0.83**	-0.49*	-0.09	-0.51*	0.84**
IVDMD		0.93**	-0.92**	-0.92**	-0.88**	-0.56*	0.72**	0.91**	0.91**	0.57**	0.19	0.68**	-0.76**
CP			-0.96**	-0.92**	-0.82**	-0.54*	0.70**	0.96**	0.97**	0.71*	0.29	0.72**	-0.76**
CWC				-0.97**	0.87**	0.48*	-0.72**	-0.90**	-0.90**	-0.54*	-0.12	-0.59*	0.80**
ADF					0.90**	0.54*	-0.77**	-0.89**	-0.88**	-0.50*	-0.11	-0.53	0.86**
ADL						0.52*	-0.72**	-0.81**	-0.80**	-0.51*	-0.13	-0.43	0.83**
						Little bluestem							
DM	-0.71**	-0.79**	0.57*	0.56**	0.68**	-0.53*	-0.58**	-0.68**	-0.83**	0.47*	0.58**	-0.75**	0.59**
IVDMD		0.83**	-0.25	-0.63**	-0.86**	0.18	0.19	0.77**	0.90**	-0.28	-0.61*	0.73**	-0.62**
CP			-0.33	-0.40	-0.60**	0.14	0.31*	0.97**	0.92**	-0.01	-0.45*	0.94**	-0.36
CWC				0.44	0.24*	-0.81**	-0.71**	-0.17	-0.33*	0.43**	0.57*	-0.27	0.45**
ADF					0.77**	-0.59**	-0.33	-0.28*	-0.48**	0.63**	0.57*	-0.28*	0.58**
ADL						-0.40	-0.18	-0.54**	-0.77**	0.57**	0.47*	-0.50*	0.68**

† Crude protein

*, ** Significant at the 0.05 and 0.01 levels, respectively

‡ Data based on 19 pairs

Table 8. Correlation coefficients among selected comparisons of dry matter, IVDMD, crude protein, cell wall constituents, acid - detergent fiber and lignin, and several minerals for switchgrass and indiangrass.

	IVDMD	CP†	CWC	ADF	ADL	Ca	Mg	P	K	Cu	Fe	Mn	Zn
Switchgrass													
DM‡	-0.79**	-0.68**	0.63**	0.70**	0.76**	0.40**	-0.44*	-0.84**	-0.78**	0.27*	0.71**	-0.55*	0.58**
IVDMD		0.91	-0.85**	-0.90**	-0.94**	-0.68*	0.48	0.88**	0.87**	-0.47	-0.63*	0.50	-0.70**
CP			-0.75	-0.91**	-0.88**	-0.56**	0.45	0.70**	0.75**	-0.21*	-0.49*	0.37**	-0.58**
CWC				0.89	0.75**	0.63**	-0.24	-0.79**	-0.63**	0.49	0.53*	-0.64	0.66**
ADF					0.88	0.70**	-0.27*	-0.79**	-0.77**	0.40*	0.52**	-0.42	0.72**
ADL						0.71	-0.46	-0.85	-0.90	0.49	0.59	-0.41	0.78
Indiangrass													
DM	-0.78**	-0.76**	0.75**	0.70**	0.63**	-0.08	-0.57**	-0.78**	-0.76**	-0.11	-0.12	0.20	0.31**
IVDMD		0.94	-0.86**	-0.94**	-0.89**	-0.26	0.66**	0.82**	0.92**	0.12	0.19	-0.11	-0.58**
CP			-0.86	-0.93**	-0.91**	-0.20	0.65**	0.81**	0.93**	0.12	0.19	0.11	-0.64**
CWC				0.88	0.81**	-0.14	-0.68**	-0.67**	-0.74**	0.26	0.10	-0.05	0.62**
ADF					0.92	0.10	-0.60**	-0.70**	-0.87**	-0.08	-0.20	-0.06	0.74**
ADL						0.26	-0.64	-0.66	-0.86	-0.04	-0.15	-0.03	0.64

† Crude protein
*,** Significant at the 0.05 and 0.01 levels, respectively
‡ Data based on 19 pairs

case in 1977, indiangrass had higher IVDMD values than big bluestem. Over the same collection period, i.e., September 9 - November 1, both species had higher IVDMD values in 1978 than in 1977.

The concentration of crude protein in the leaf portion of both species declined rapidly during the fall (Table 9). The protein concentration of indiangrass leaves was greater than big bluestem leaves for all harvest dates. The pattern for big bluestem and indiangrass stem crude protein concentration was similar to that noted for IVDMD. For the whole plant sample, the crude protein concentration of both big bluestem and indiangrass declined about 50% during the collection period. Over the same collection period, crude protein values were higher in 1978 than in 1977, particularly for the final three sampling dates.

Since little plant growth occurred during the collection period, the decline in the whole plant crude protein concentration appeared to be due to declines in leaf crude protein concentration. This is in agreement with a report by Perry and Baltensperger (1979), although their harvest period was from June 8 to August 17, which included the development of an inflorescence.

These findings are not in total agreement with a study on the quality characteristics of big bluestem and switchgrass in Pennsylvania (Griffin, 1979). However, in the latter study the harvest period was from late June until mid-August and, therefore, did not include the fall maturation period studied in the survey reported herein.

Over the survey collection period, the crude protein concentration

Table 9. Percent IVDMD*, crude protein, cell wall constituents, acid - detergent fiber and lignin in the leaf and stem fractions as well as whole plants of big bluestem and indiangrass (1978).

1978 harvest date	IVDMD			Crude protein			CWC			ADF			ADL		
	LB†	Stem	Plant	LB	Stem	Plant	LB	Stem	Plant	LB	Stem	Plant	LB	Stem	Plant
	%														
Big bluestem															
13 - 9	51.9	36.0	46.8	7.9	2.9	4.9	66.4	80.2	72.9	35.9	50.6	43.1	4.3	7.2	5.5
21 - 9	50.0	37.1	41.4	8.0	3.0	4.9	68.0	77.7	74.0	37.3	50.1	45.1	5.4	7.9	6.5
27 - 9	50.9	36.1	39.5	5.8	2.7	3.8	69.0	77.9	73.9	40.0	50.8	46.5	5.3	7.3	7.3
4 - 10	49.6	33.0	39.1	5.0	2.7	3.4	68.2	79.3	76.8	42.1	50.9	48.5	6.4	7.7	7.2
10 - 10	37.0	31.2	32.8	3.5	2.7	2.7	70.7	81.0	78.7	44.5	51.7	50.6	6.9	8.0	8.4
1 - 11	38.2	33.0	32.5	3.5	2.1	2.4	74.9	84.3	82.3	48.3	54.8	52.2	6.5	8.1	8.3
Mean	46.3	34.4	38.7	5.6	2.7	3.7	69.5	80.1	76.4	41.4	51.5	47.7	5.8	7.7	7.2
SD‡	6.8	2.3	5.4	2.0	0.3	1.1	3.0	2.4	3.6	4.6	1.7	3.4	1.0	0.4	1.1
Indiangrass															
13 - 9	62.2	37.3	52.1	8.8	3.4	6.4	67.3	74.9	70.9	37.4	47.9	41.3	3.6	6.1	4.8
21 - 9	60.9	45.8	49.0	8.1	4.0	5.2	65.7	76.3	70.2	36.1	47.4	44.0	3.1	6.7	4.1
27 - 9	57.0	43.3	48.4	7.3	4.3	4.5	65.9	75.5	72.5	36.5	47.7	44.2	3.6	6.8	5.7
4 - 10	52.6	39.3	40.7	5.5	3.6	4.3	69.7	75.5	73.5	39.4	46.4	45.0	3.5	6.5	5.8
10 - 10	53.7	43.0	44.4	4.4	3.3	4.1	67.4	74.1	72.0	39.3	47.2	44.4	3.4	6.8	4.9
1 - 11	44.4	33.8	42.2	3.8	3.1	3.5	76.1	81.1	77.0	46.3	52.9	48.4	5.3	8.6	6.8
Mean	55.1	40.4	46.1	6.3	3.6	4.7	68.7	76.2	72.7	39.2	48.3	44.6	3.8	6.9	5.4
SD	6.5	4.4	4.4	2.0	0.5	1.0	3.9	2.5	2.4	3.8	2.3	2.3	0.8	0.9	0.9

* Urea added to fermentation flask at the rate of 3.2% N per unit weight of tissue.
† Leaf blade
‡ Standard deviation

of big bluestem declined 0.09, 0.02, 0.05 percentage points/day for leaf, stem, and whole plant samples, respectively, and the crude protein concentration of indiangrass declined 0.10, 0.006, and 0.06 percentage points/day for leaf, stem, and whole plant samples, respectively. This is in agreement with Perry and Baltensperger (1979) who reported that the crude protein concentration of big bluestem leaves declined at a rate of 0.07 percentage points/day. Griffin (1979) found that the rate of decline of crude protein concentration in the stems was twice that in the leaves, although his sampling period included only from stem initiation to anthesis initiation (June 26 to August 8).

Cell wall constituents (CWC), acid - detergent fiber (ADF), and acid - detergent lignin (ADL) of the whole plants of both species increased during the collection period (Table 9). As would be expected, stems had higher concentrations of these fractions than did the leaves. For both species the increase in CWC and ADF that occurred was greater for the leaf fraction than it was for the stem fraction. Over the same collection period, the three fractions were lower in 1978 than in 1977.

Mineral Components

The concentrations of calcium, magnesium, phosphorus, and potassium in big bluestem and indiangrass are shown in Table 10. Calcium concentrations fluctuated within the collection period so that clear trends were not evident. Leaf calcium concentrations were much higher than stem calcium concentrations for both species. Calcium concentrations were lower in the 1978 samples than in the 1977 samples.

Concentrations of magnesium in the big bluestem samples declined with advancing maturity, a pattern not evident for the indiangrass samples. The magnesium concentrations of leaf and stem fractions, for both species, were roughly equal. As was the case in 1977, magnesium concentrations of all plant tissues were low.

The phosphorus concentration of indiangrass samples on November 1 were substantially lower than those observed for other dates. For big bluestem, no seasonal pattern was evident although there was a decline in phosphorus concentrations in leaf blade and stem after October 4. In most cases, phosphorus concentrations were higher in the leaves compared to the stems. Indiangrass phosphorus concentrations were higher in the 1978 samples than in the 1977 samples.

Concentrations of potassium in both grasses generally declined during the collection period, as was the case in 1977. In both species, the potassium concentrations of the leaves were greater than those of stems for the September 9 - September 27 collection period while the reverse was true for the October 4 - November 1 period. Potassium concentrations of both species were greater in 1978 than in 1977.

The concentrations of copper, iron, manganese, lead, and nickel found in both species were greater for the leaves than for the stems (Table 11). A contributing factor of this observation, at least for some elements, may have been airborne particulate pollutants. Indiangrass had greater concentrations of copper, lead, and nickel than big

Table 10. Percent calcium, magnesium, phosphorus, and potassium in the leaf and stem fractions as well as the whole plants of big bluestem and indiangrass (1978).

1978 harvest date	Ca			Mg			P			K		
	LB*	Stem	Plant	LB	Stem	Plant	LB	Stem	Plant	LB	Stem	Plant
	%											
Big bluestem												
13 - 9	0.35	0.08	0.15	0.07	0.07	0.06	0.12	0.08	0.11	0.82	0.73	0.92
21 - 9	0.44	0.08	0.18	0.10	0.09	0.07	0.13	0.07	0.10	1.01	0.94	1.01
27 - 9	0.38	0.08	0.15	0.06	0.06	0.06	0.09	0.07	0.08	1.08	0.67	0.83
4 - 10	0.46	0.08	0.19	0.04	0.05	0.04	0.12	0.12	0.11	0.60	0.69	0.61
10 - 10	0.35	0.07	0.13	0.04	0.06	0.05	0.07	0.10	0.08	0.66	0.96	0.65
1 - 11	0.29	0.07	0.12	0.03	0.02	0.03	0.06	0.08	0.09	0.18	0.51	0.42
Mean	0.38	0.08	0.15	0.06	0.06	0.05	0.10	0.09	0.10	0.72	0.75	0.74
SD†	0.06	0.01	0.03	0.03	0.02	0.01	0.03	0.02	0.01	0.33	0.17	0.22
Indiangrass												
13 - 9	0.29	0.05	0.16	0.02	0.05	0.08	0.28	0.16	0.21	1.43	1.14	1.20
21 - 9	0.22	0.04	0.15	0.08	0.05	0.06	0.27	0.18	0.21	1.24	1.05	1.17
27 - 9	0.22	0.04	0.10	0.09	0.05	0.05	0.24	0.18	0.18	1.10	0.98	1.03
4 - 10	0.25	0.07	0.17	0.08	0.06	0.06	0.21	0.16	0.20	0.98	1.03	0.95
10 - 10	0.30	0.07	0.18	0.10	0.07	0.07	0.23	0.17	0.19	0.95	1.05	0.95
1 - 11	0.25	0.07	0.15	0.04	0.05	0.06	0.08	0.11	0.10	0.28	0.61	0.43
Mean	0.26	0.06	0.15	0.07	0.06	0.06	0.22	0.16	0.18	1.00	0.98	0.96
SD	0.03	0.02	0.03	0.03	0.01	0.01	0.07	0.03	0.04	0.39	0.19	0.28

*Leaf blade
†Standard deviation

bluestem. The two species were roughly equal in manganese and zinc concentrations.

Although the copper concentrations in 1978 were slightly higher than those observed in 1977 they were still within the range observed by Taylor and Allinson (1979) for alfalfa. Iron concentrations, particularly for leaf tissues, increased markedly during the fall period and largely contributed to the substantially greater iron concentrations of whole plant tissues observed in 1978 compared to 1977. Zinc concentrations of the whole plants were somewhat lower in 1978 compared to 1977. However, they were substantially higher than those reported by Taylor and Allinson (1979) for alfalfa.

Lead concentrations, especially for leaf tissues, were substantially greater than those observed by Taylor and Allinson (1979). Over a two - year period the latter study reported a range of 2.8 - 33.2 ppm for lead concentrations in alfalfa. In the present study, lead concentrations of both species generally increased during the sampling period. The greater values observed for indiangrass compared to big bluestem may have been due to the very rough cuticular leaf surface of indiangrass (Clarke, Campbell, and Shevkenek, 1944). Lead concentration possibly reflected the proximity of the sampling site to a moderately - high traffic density highway, plus a long growing season without foliar removal.

SUMMARY AND CONCLUSION

Big bluestem, little bluestem, switchgrass, and indiangrass

Table 11. Concentration of copper, iron, manganese, zinc, lead, and nickel in the leaf and stem fractions as well as the whole plants of big bluestem and indiangrass (1978).

1978 harvest date	Cu			Fe			Mn			Zn			Pb			Ni		
	LB*	Stem	Plant	LB	Stem	Plant	LB	Stem	Plant	LB	Stem	Plant	LB	Stem	Plant	LB	Stem	Plant
	ppm																	
Big bluestem																		
13 - 9	12.7	9.1	11.7	282	73	177	63	43	50	107	154	152	48	12	28	12.3	4.6	7.6
21 - 9	11.5	9.4	11.9	195	56	141	102	55	71	54	90	81	36	11	28	6.0	3.0	6.0
27 - 9	12.9	11.3	11.4	344	73	195	89	50	61	60	82	88	64	11	27	9.0	1.6	4.5
4 - 10	13.2	8.5	9.5	494	148	348	109	57	73	93	128	101	100	22	62	9.2	6.0	9.2
10 - 10	13.9	9.2	9.8	463	108	260	145	62	81	68	105	83	100	23	58	10.6	6.2	3.0
1 - 11	13.4	10.7	12.9	544	232	263	101	42	55	84	94	133	111	36	64	9.1	7.6	3.0
Mean	12.9	9.7	11.2	387	115	231	102	52	65	78	109	106	76	19	44	9.4	4.8	5.6
SD†	0.8	1.1	1.3	135	66	75	27	10	12	21	27	29	31	10	19	2.1	2.2	2.5
Indiangrass																		
13 - 9	15.8	12.3	11.8	188	78	226	86	66	66	64	116	84	89	28	90	6.1	7.8	12.3
21 - 9	14.2	8.4	14.0	179	80	120	57	45	70	83	124	98	73	28	51	15.1	8.9	7.6
27 - 9	17.0	13.3	16.6	208	119	134	58	53	58	92	124	133	95	40	47	13.6	7.6	6.1
4 - 10	16.6	13.0	19.5	302	225	288	78	63	78	72	151	119	125	51	109	9.1	6.1	13.5
10 - 10	16.8	12.0	14.6	276	74	242	73	54	70	73	109	100	93	36	72	12.3	13.5	12.4
1 - 11	13.7	12.0	13.5	471	121	245	78	52	67	113	171	104	170	64	98	9.1	10.6	9.1
Mean	15.7	11.8	15.0	271	116	209	72	56	68	83	132	106	108	41	78	10.9	9.1	10.2
SD	1.4	1.8	2.7	110	57	67	11	8	7	18	24	17	35	14	25	3.4	2.6	3.0

* Leaf blade
† Standard deviation

samples were collected at approximately weekly intervals from June 14 until November 1 in 1977. Whole plant samples, as well as leaf and stem fraction samples, of big bluestem and indiangrass were collected from September 13 - November 1 in 1978. Quality and mineral analyses were conducted on all samples.

In 1977, switchgrass reached anthesis during the period of early- to mid-July. The other warm-season grasses did not reach this stage until early- to mid-August. The IVDMD declined throughout the collection period. Indiangrass generally had higher IVDMD values compared to the other grasses. Compared to cool-season grasses, the IVDMD values of the warm-season grasses were rather low. However, it has been pointed out that the IVDMD technique does underestimate the in vivo digestible dry matter of switchgrass and big bluestem (Griffin et al., 1980).

The crude protein concentrations of the grasses in 1977 ranged from approximately 4 - 10% during the July - August period. During the collection period the crude protein concentration declined 0.06 - 0.08 percentage points per day.

For all four grasses the concentration of CWC was high. However, the changes in concentrations that occurred- as indicated by the coefficients of variation- were less for CWC than for the other parameters measured. Cell wall constituents, ADF, and ADL increased during the June - November period.

The grasses were growing on an acidic infertile site and therefore it may be inappropriate to make stringent inferences from their mineral

concentrations. However, the magnesium concentrations of all of the grasses were consistently low as were the phosphorus concentrations of the grasses from the late - summer period onwards. The concentrations of phosphorus, magnesium, and potassium declined consistently throughout the collection period.

The sampling period in 1978 was much shorter than that used in 1977 and only big bluestem and indiangrass were collected. Leaf blades had higher concentrations of IVDMD, crude protein, calcium, phosphorus, copper, iron, manganese, lead, and nickel than did stems. Changes in grass quality - as measured by IVDMD, crude protein, and CWC - appeared to be dominated by changes in the leaf tissues rather than the stem tissues.

Acknowledgement: The authors gratefully acknowledge Miss M. Woodward for assistance in performing mineral analyses.

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