YIELD AND QUALITY OF OLD WORLD BLUESTEM GRASSES (*BOTHRIOCHLOA SPP.*) AS AFFECTED BY CULTIVAR, PLANT PART, AND MATURITY

By

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CHAPTER I

INTRODUCTION

This dissertation is composed of four chapters. Chapter II contains general information and a review of literature pertinent to the subject matter. Chapters III and IV are prepared as separate papers for publication in a professional journal.

Old world bluestems (Bothriochloa-Dichanthium-Capillipedium Complex) are warm-season bunchgrasses mainly of European and/or Asiatic origin. Interest in these grasses is based primarily on their apparent superiority to North American forms (Genus Andropogon) in persistence under grazing and higher production potential due to greater ability to respond to fertilizer additives[1]. They also are adapted to a wide range of climatic and edaphic conditions. Consequently, utilization of Old World Bluestems for pasture use and soil conservation in the southern Great Plains has expanded rapidly during the past decade.

Yield and quality information from forages is useful in plant breeding and animal production programs. As a quality parameter, digestibility of feed is an important factor affecting animal production. Perhaps equally important, are the chemical composition param-

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1. Celarier, R. P., and J. K. Harlan. 1955. Studies on Old World Bluestems, OK. A & M Coll. Agr. Exp. Stn. Tech. Bull. No. T-58

eters which provide information on factors that limit digestibility.

While some data are available on yield parameters of old world bluestems, information on quality characters such as *in vitro* dry matter disappearance (IVDMD), neutral detergent fiber (NDF) acid detergent fiber (ADF), acid detergent lignin (ADL) and crude protein (CP) is limited or nonexistent.

The nutritive value of forages can be underestimated by analyzing only whole plant samples. Stem, leaf, and leaf sheath portions of plants differ in quality depending on their role in the plant and the stage of maturity. Hence, patterns of change in digestibility and chemical composition of whole plants and plant parts of old world bluestem cultivars at different stages of maturity are of interest.

The major objective of this research was to evaluate relationships between quality, chemical composition, and yield parameters of whole plants and plant parts of old world bluestem cultivars at various stages of maturity.

CHAPTER II

GENERAL INFORMATION AND LITERATURE REVIEW

Old world bluestems (OWB), also known as Asiatic bluestems, belong to the Bothriochloa-Dichanthium-Capillipedium cytotaxonomic complex of grasses, primarily of Asiatic and European origin. They are warm-season bunchgrasses of tropical and subtropical affinity. The range of adaptation varies from extremely high rainfall sites (550 cm/year) to deserts receiving as little as 10 cm of annual precipitation (20).

The group is best adapted to fine-textured soils, however, they do well on soils varying in texture from sandy loam to tight clay (10).

Ecologically, most OWB do not behave as climax plants, but rather appear to be best fitted to some stage of secondary succession (20). They tend to thrive under grazing and other disturbances. Overall, the plants are easy to establish, and they reproduce freely by seed (20). Most OWB species are prolific seed producers, however, harvesting and processing of seed is very difficult because of their indeterminate flowering habit and chaffy seed unit characteristics (1).

The taxonomic, cytological, and morphological characteristics of OWB have been extensively studied (5, 12, 13, 18, 19, 20, 21, 22). Cytological investigations revealed a series of chromosome numbers ranging from 2n=2X=20 to 2n=18X=180 in multiples of 10. Diploid species reproduce sexually while polyploid species reproduce predominantly by apomixis (7, 21).

The disastrous drouth and depression of the 1930's resulted in dust storms, crop failures, and farm abandonment and pointed to the need for soil and water conservation in the Great Plains (17). Millions of acres of abandoned farmland needed reseeding. This effort, undertaken by the U.S. Department of Agriculture, resulted in the use of Crested Wheatgrass (Agropyron desertorum) in the north, and prompting later, the recognition of need for improved grass varieties in the south.

Interest in OWB arose because of their tolerance to adverse climatic conditions and apparent superiority to America relatives in production, persistence and response to fertilization.

The first recorded introduction of an OWB grass into the USA, is perhaps that of Bothriochloa ischaemum into California from Amoy, China in 1917 (5). This introduction was then dispersed from California to Washington, DC (1932), to Stillwater, OK (1935), to Woodward, OK (1937) and to College Station, Texas (1937). It was released by the Texas Agric. Exp. Stn. as Texas yellow beardgrass in 1949. Meanwhile, the grass had also been taken to the Angleton Experiment Station (1924) from where it apparently reached the King ranch in Texas. Following increase and propagation by private growers and the Soil Conservation Service (SCS), it was released as 'King Ranch' bluestem (5). In 1937, an adventitious form of Bothriochloa ischaemum was tested and released as the 'Elkan' variety. An earlier introduction to the West Indies was that of "Hurricane grass", Bothriochloa pertusa (L.) A. Camus, which subsequently showed some promise along the Gulf Coast of the U.S. (5).

Another traceable introduction is that of 'Caucasian' bluestem, Bothriochloa caucasica (Trin.) C. E. Hubbard, received by the USDA from the Botanic Garden, Tiflis Caucasus Russia on Feb 4, 1929. The grass was first grown at the Texas Chillicothe substation; however, its increase and distribution was primarily made by SCS personnel at Manhattan Kansas. This grass has been commercially available since the 1930's.

In the early 1950's personnel of the Oklahoma Agricultural Experiment Station in Stillwater began to assemble the largest collection of OWB ever amassed in the western hemisphere. This collection was used in an extensive study of the plant group and recently has been the source of new cultivars developed and released as pasture grasses for Oklahoma and surrounding states.

General Varietal Information

Four old world bluestem cultivars were used in this investigation because of their adaptation to and widespread use in Oklahoma. They were: 'Plains', Caucasian, 'Ganada' and 'WW-Spar'.

Plains bluestem, Bothriochloa ischaemum (L.) Keng. Var. 'ischaemum', was cooperatively released in 1972 by the Oklahoma Agricultural Experiment Station and the USDA-ARS (44, 45). The Plains cultivar is used in Oklahoma, Texas, Missouri, Arkansas, and Kansas (10). It is a composite of some 30 morphologically similar apomictic lines. Plains is not as winter hardy as Caucasian, but it is hardy as far north as southern Kansas (10).

Caucasian bluestem, Bothriochloa caucasica (Trin.) C. E. Hubbard was introduced from Russia in 1929. It was the first OWB to be used as forage. Caucasian is more winter hardy than other OWBs, and is adapted to Oklahoma, Texas, Kansas, Missouri and Arkansas (10).

Ganada bluestem, Bothriochloa ischaemum (L.) Keng. Var. ischaemum was cooperatively released by the New Mexico, Colorado, and Arizona, Agricultural Experiment Stations, and the USDA-SCS in 1979 (47). The grass originated from old Turkestan in Russia. The area of adaptation, although not well defined, includes New Mexico, Arizona, Colorado, Texas, and Oklahoma.

WW-Spar bluestem, Bothriochloa ischaemum (L.) Keng. Var. ischaemum, is one of the components of Plains bluestem. It was rele as-ed in 1981 cooperatively by the USDA-ARS, Southern Plains Range Research Station, Woodward Oklahoma and the Oklahoma Agriculture Experiment Station. WW-spar is a single apomictic biotype from Pakistan. It is purported to be more determinate in flowering habit and higher in seed production than Plains (10). It had excellent persistence and spring vigor when grown in Kansas, Illinois, Colorado, Oklahoma, and Texas.

Factors Affecting Forage Quality

Maturity

Stage of plant maturity seems to be the most important factor affecting plant chemical composition and digestibility (2, 32, 35, 36, 39, 40). As grasses mature, the protein content decreases (23, 26, 41), the fibrous fraction increases (28, 29) and digestibility of the cell wall content fraction declines (51, 52). Decrease in digestibility with advancing maturity is mainly due to an increase in lignin or lignified tissue (27, 28, 37). According to Minson et al. (32), the rate of this decrease depends on the type of herbage and the stage of morphological development.

Pritchard et al. (38) also reported a decline in IVDMD for timothy (Phleum pratense L.), orchard (Dactylis glomerata L.), brome (Bromus inermis Leyss), reed canary (Phalaris arundinacea L.), tall fescue (Festuca arundinacea Schreb), and mountain rye (Secale montanum Guss.) grasses with advancing maturity. The rate of decline for heads and stems was greater than that for leaves. In four weeping lovegrass (Eragrostis curvula (Schrad.) Nees.), varieties, seasonal trends showed that IVDMD declined 0.46 percentage unit per day from jointing to anthesis (53). Averaged over all harvests, IVDMD values for 'Morpa' and 'Ermelo', were significantly higher than those of 'Common' and '673'. The in vitro dry matter digestibility (IVDMD) study of eastern Canadian grasses by Pritchard et al. (38) showed that IVDMD was not governed solely by stage of maturity, nor by date of sampling, but by an interaction of the two factors together with characteristics of the species.

Recent studies have demonstrated a decrease in dry matter digestibility of selected varieties of OWB with advancing maturity (24).

Leaf and Stem Quality

The aging of forage is frequently associated with a decrease in leafiness and an increase in the stem to leaf ratio. It is generally assumed that nutritive value of the leaves of forages is superior to that of the stems. Consequently, the proportion of leaf material has been widely used as a criterion in the judging and grading of hay, and also in the selection of new forage varieties. However, this may vary with the species. The IVDMD of immature stems of timothy, orchard grass and bromegrass was higher than corresponding values of leaves (34). However, the rate of decline of digestibility with advancing maturity was greater in stems than in leaves for each species. It was concluded that leafiness for these grasses, was a poor indicator of digestibility since the less digestible orchardgrass contained the most leaves.

In vitro studies by Minson et al. (31, 32) with two varieties of ryegrass and one of orchardgrass indicated that digestibility of the leaf lamina fraction decreased 0.15% per day with advancing maturity. Leaf sheaths and stem fractions, decreased more rapidly (0.40% and 0.70% per day, respectively) than the lamina with increasing maturity.

Leaves usually have from 1.5 to 3 times the protein percentage of stems and are higher in the other nutrients as well (14, 15, 25, 43, 46). Available evidence indicates that grazing animals are selective in quality of forage consumed. Hardison et al. (16), found that plant material eaten by grazing animals was higher in protein, and lower in fiber than that cut and fed from adjoining pastures containing the same species and receiving the same treatment. This preference for leaves, indicates their importance in a breeding program for quality.

Fiber

Van Soest (51) divided forage dry matter into two fractions: cell content (CC), or neutral detergent soluble (NDS), and cell wall constituents (CWC), or neutral detergent fiber (NDF). The NDF is further divided into acid detergent soluble (ADS) containing water insoluble protein and hemicellulcse and acid detergent fiber (ADF) containing essentially insoluble lignin, cellulose, and minerals. Cell contents and overall digestibility are positively correlated (30). On the other hand, fiber components are inversely related to digestibility (33, 48). Van Soest (50) also reported that voluntary intake is reduced when the CWC fraction exceeds 55% of forage dry matter.

Lignin is believed to be the primary causative agent involved in the incomplete digestion of cellulose and hemicellulose. Hypotheses of the manner in which lignin affects digestibility include: "incrustation" (8, 9, 11) and/or direct linkage of lignin to structural carbohydrates (3, 4). Incrustation refers to the entrapment of nutrients within lignified cell walls. One limitation in using lignin as a predictor of dry matter digestibility, especially in legumes, is that the cellular contents are not lignified, but rather are completely available (51). Therefore, due to the relationship between forage dry matter content and lignin, Sullivan (42) suggested that the regression of lignin on dry matter digestibility is different for every species of forage. As pointed out by Van Soest (49), this is particularly true for different families and groups of forages.

Cellulose, hemicellulose, and lignin concentrations increase with maturation of grasses (26). Cogswell and Kamstra (6) also reported increases in cellular and lignin contents in four prairie grasses from June to September. Similarly, Horn and Taliaferro (24) reported an increase acid detergent lignin (ADL) in five OWB cultivars from July September.

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CHAPTER III

YIELD AND DIGESTIBILITY OF FOUR OLD WORLD BLUESTEM CULTIVARS (BOTHRIOCHLOA SPP.,) AS AFFECTED BY PLANT PART AND MATURITY

ABSTRACT

Old world bluestems (Bothriochloa spp.) have been used in the U.S. for over 60 years but few data are available on effects of management or cultivar differences for forage yield and quality. Field experiments were conducted on a Kirkland silt loam (Uderic Paleustoll) soil for 2 years (1982-1983), in order to assess the yield and quality of four such cultivars as affected by maturation and plant part. The experimental design was a split-split plot, in a randomized complete block, with four cultivars, 10 harvest dates and three plant parts (whole plant, stem, and leaf). Plots were harvested at weekly intervals at a height of 1.3 cm. Response variables were dry matter (DM) yield, (kg ha^{-1}) and in vitro dry matter disappearance (IVDMD), (g.Kg^{-1}).

The Ganada cultivar consistently had the lowest leaf, stem and whole plant DM yields both years. The Caucasian cultivar had higher leaf, stem and whole plant DM yields than Plains and WW-Spar in 1983, but the DM yields of these cultivars were similar in 1982. Overall DM yields increased at rates of 393, 41 and 327 kg ha^{-1} weekly for

plants, leaves, and stems, respectively. The Caucasian cultivar had the highest and Ganada the lowest weekly rate of increase. Quadratic and linear equations satisfactorily fit the yield data in 1982 and 1983, respectively.

The IVDMD averaged over plant parts declined 6.5, 6.2, 4.4 and 5.4 $g.kg^{-1}$ daily for Plains, Caucasian, Ganada and WW-Spar, respectively. The decline was quadratic in nature and faster in stem fractions. Cultivar IVDMD differences were consistent over plant parts. The Ganada and Caucasian cultivars had the highest and lowest IVDMD concentrations, respectively. The Plains and WW-Spar cultivars had IVDMD values of similar magnitude and intermediate to those of Ganada and Caucasian.

INTRODUCTION

Old world bluestems (Bothriochloa spp.) are perennial, warm-season, bunchgrasses of Eurasian origin (3, 15). They are good pasture and erosion-control grasses in the Southern Great Plains and other regions of the USA. They combine attributes of good forage yield potential, acceptable forage quality, the ability to increase in stand density and area via seed dispersal and tillering, and a superior ability to tolerate various stresses without loss of stand. They are particularly useful in reclamation of depleted rangelands or abandoned farmlands with fine textured, sloping soils characteristic of millions of hectares in the Southern Great Plains.

Despite their extensive use by livestock producers in the southern Great Plains, few data are available on the yield and quality of the old world bluestems (OWB) in general, and newly released OWB cultivars in particular.

Comparative forage yield tests in Oklahoma have shown Plains to be less productive than Caucasian but equal in persistence (16). Dalrymple et al. (1) reported preliminary yield test results of commercially available OWB. The Caucasian and Plains cultivars had the highest yields (about 5712 kg ha^{-1}) and Ganada the lowest (about 5176 kg ha^{-1}).

Taliaferro et al. (16) found that the IVDMD of the Plains cultivar was higher than that of Caucasian (49.3 vs 45.4%). The IVDMD of both cultivars decreased as the growing season advanced. Horn and Taliaferro (5), studied seasonal changes in IVDMD values of five OWB cultivars including Plains and Caucasian. A downward trend in IVDMD occurred as the season progressed though the total decline was not great. The lowest IVDMD values were reached in August.

The nutritional value of forage may be underestimated by analyzing only whole plant samples because livestock seldom consume whole plants; but rather selectively graze individual parts (6). The parts of a plant (inflorescence, leaf blade, leaf sheath and culm) differ in quality (6). Generally, the nutritive value of leaves is superior to that of stems (6, 7, 8, 17). <u>In vitro</u> studies by Minson et al. (7, 8) with ryegrasses, fescue, timothy and cocksfoot grasses separated into leaf lamina, leaf sheath, stem, inflorescence, and dead material, indicated that digestibility of the leaf lamina fraction decreased 0.10% per day with advancing maturity. Leaf sheaths and stem fractions decreased more rapidly than the lamina with increasing maturity (0.40% and 0.70% per day, respectively). Yet, stem fractions were more digestible than leaf fractions in immature stages of growth. Similar results were reported by Mowat et al. (10).

The objectives of this study were to: a) characterize the forage yield and quality differences of whole plant and component plant parts of four OWB cultivars as affected by stage of maturity, and b) ascertain the relationships between yield patterns and IVDMD.

MATERIALS AND METHODS

This study was conducted in 1982 and 1983 on the Agronomy Research Station, Stillwater, Okla. The soil type was a Kirkland silt loam (Uderic Paleustoll). The field plot design was a randomized complete block design with four replications. The four OWB cultivars were Plains (Bothriochloa ischaemum (L.) Keng. Var. ischaemum), Caucasian (B. caucasica (Trin.) C. E. Hubbard), Ganada (B. ischaemum (L.) Keng. var. ischaemum) and WW-Spar (B. ischaemum (L.) Keng var. ischaemum). Plots were 6x.6 m, each consisting of 5 rows spaced 15 cm apart. The test was seeded 28 July, 1980.

The nursery was uniformly staged at a height of about 1.00 cm, 22 June, 1982 and 25 May, 1983. The plots were fertilized with 120 kg N/ha soon after staging. Plots were then divided into ten .5 m^2 subplots. Harvest dates (1 through 10) were randomly assigned to subplots. Harvesting was started 3 weeks after staging; and continued at weekly intervals for 10 weeks. Plants in subplots were clipped at 1.3 cm from ground level. Subplot total green weight was recorded for yield measurements and two subsamples were taken. One subsample was oven dried at 65°C for 7 days and used to convert subplot green yield weights to dry matter yields. The second subsample was frozen and later separated into leaf, stem, and head (inflorescence) components.

Leaves consisted of blade plus sheath. After separation, the respective plant parts were dried in a forced draft oven at 65°C for 7 days. Dry matter weights of leaves, stems, and inflorescences were used to estimate the percentage of each plant part in the subplot total dry weight. All dried samples were then ground first through a 5 mm screen in a Wiley Mill[1] and through a 1 mm screen in a UDY Cyclone Mill[1]. This resulted in 20 to 30 g of ground forage which was used to determine forage quality. The IVDMD was determined for each dried sample with the exception of inflorescence samples.

IVDMD was measured by near infrared reflectance (NIR) spectroscopy using a Neotec Model 6100 monochromator[1]. Sixty-four scans of each sample with monochromatic light in the near infrared region, from 1,100 to 2,500 nm, were averaged and stored on a Digital Equipment Corporation mini-computer PDP 11L-03[1]. Seven hundred data points at 2.0 nm intervals were recorded for each sample. The monochromator was calibrated with IVDMD data from the laboratory analysis of 480 forage samples (50% of all samples including stems, leaves, and whole plants). The 480 samples were drawn from two randomly selected replications. Percent IVDMD for the laboratory analysis was determined in triplicate using a modified Tilley and Terry technique (9). Calibration of the monochromator was achieved using the computer software developed at Pennsylvania State University (12). The software combined NIR reflectance data with the laboratory analyses, performed the nec-

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[1]Reference to a company or product name does not imply approval or recommendation of the product by the Oklahoma Agriculture Experiment Station to the exclusion of others which might be suitable.

essary mathematical transformations (log 1/R, 1^{st} and 2^{nd} derivatives), and used a modified stepwise linear regression procedure to find the wavelengths most useful for predicting the desired forage. Seven calibration equations resulted and included 1 to 10 wavelengths and their regression coefficients for predicting forage quality characters. On the basis of the R-square, bias, and standard error of prediction statistics, an equation was chosen to predict the IVDMD from the reflectance spectra of the remaining samples.

An overall statistical analysis was first conducted on each response variable using ANOVA procedures for a split-split plot arrangement. Data were then analyzed within year and by plant part to assess cultivar differences and the effects of harvest dates. The Least Significant difference test of treatment means backed by significant F-test was used to determine differences among cultivars and maturity stages (14). Orthogonal polynomials were used to partition the harvest dates and harvest dates x year sum-of-squares into linear, quadratic, and deviation from quadratic components. Yield results were correlated with whole plant IVDMD values to ascertain the significance of their relationship.

RESULTS AND DISCUSSION

There were significant first, second, and third order interactions involving cultivars, harvest dates, years, and plant parts, for yield and IVDMD (Appendix Table B1). Therefore, results are reported by year and plant part.

Yields of Dry Matter. Differences in whole plant, leaf, and stem DM yield due to cultivar and harvest date were highly significant

($P<.01$) each year (Appendix Tables B2-B7). The significant ($P<.05$) cultivar x harvest date interactions in 1982 were caused more by differences in magnitude of response, than by changes in cultivar rank. The Ganada cultivar had the lowest ($P<.05$) yield of all components both years (Fig. 1). The Caucasian cultivar consistently had higher ($P<.05$) leaf, stem, and whole plant DM yields than Plains and WW-Spar in 1983, but the DM yield of these cultivars was similar in 1982. In 1983, the whole plant yield of Caucasian was about 17% more than Plains (Appendix Table A1). For the same year, the whole plant DM yield of Ganada was 16% and 20% lower than that of Plains and WW-Spar, respectively. In 1982, the DM yield of Ganada was about 30% lower than the average yield of Plains, Caucasian, and WW-Spar. These results agree with some previous studies (1, 13, and 16) but disagree with others (2).

Dry Matter yields of all cultivars increased significantly ($P<.01$) with advancing maturity (Fig. 1). The data satisfactorily fit second and first order polynomial equations in 1982 and 1983, respectively (Table 1). This inconsistency in DM yield trends between years was likely the result of environmental differences on growth.

The linear equations in 1983 (Table 1) revealed weekly mean DM yield increases of 393, 41 and 327 kg/ha for whole plants, leaves, and stems, respectively. The Caucasian cultivar had the highest rates of increase and Ganada the lowest. The Caucasian and Ganada whole plant yields increased at respective rates of 490 and 303 kg ha^{-1} weekly in 1983. The R^2 values obtained for leaves were smaller than those of stems (Table 1), an indication that maturation contributed more to stem DM yield.

In Vitro Dry Matter Disappearance. There were significant differences in the IVDMD of all plant parts due to cultivar and harvest dates both years (Appendix Tables B2-B7). The cultivar x harvest date interactions for the IVDMD of all plant parts were significant ($P<.01$) in 1982. These same interactions were only significant in stem fractions in 1983.

Ganada was consistently higher than other cultivars in IVDMD, while Caucasian tended to have the lowest IVDMD (Fig. 2). In 1983 Caucasian stems were higher ($P<.05$) in IVDMD than those of Plains and WW-Spar. The IVDMD values of Plains and WW-Spar cultivars were similar both years and intermediate to those of Ganada and Caucasian (Fig. 2). Cultivar differences were more noticeable in leaves than in whole plants or stems (Fig. 2). Differences obtained between Plains and Caucasian agree with previous results (5), and the low IVDMD values of Caucasian were probably due, among other factors, to its rapid growth rate and high DM yield as reported by Horn and Jackson (4).

The mean IVDMD of all cultivars and all plant parts decreased significantly ($P<.01$) with maturation (Fig. 2) with values ranging from 660 for leaves to 360 $g.kg^{-1}$ for stems within respective harvest dates. Orthogonal contrasts indicated that the data satisfactorily fit quadratic equations but different quadratic equations were required for the 2 years (Table 1).

IVDMD of whole plant samples of the Plains, Caucasian, Ganada, and WW-Spar, cultivars declined at respective mean rates of 6.5, 6.2, 4.4 and 5.4 $g.kg^{-1}$ daily. The mean IVDMD of all cultivars decreased at a rate of 5.6 $g.kg^{-1}$ daily. This rate of decline is comparable to those reported by Pritchard et al. (11) and Voigt et al. (18). The IVDMD values of immature stems were similar to corresponding values of leaves (Fig. 2). However, the rate of decline of IVDMD with advancing maturity was greater in stems than in leaves for each cultivar except Caucasian in 1982.

Correlation coefficients between IVDMD and the yield of whole plant and component parts of each cultivar at progressive maturities are shown in table 2. Highly significant negative correlations were obtained between IVDMD and yield of all component parts in all cultivars. This simply indicates that as the plants aged the yields increased while IVDMD decreased. Among cultivars, Ganada had the lowest correlation coefficient values for all plant parts. The Plains and WW-Spar cultivars had the highest correlation coefficients for stems while Caucasian had the highest value for leaves. Correlation coefficients were high for stems and low for heads. The high correlation for Caucasian and WW-Spar in heads is consistent with their high inflorescence DM yields (Appendix Table A1). This inverse relationship between yield components and IVDMD is consistent with reports for many other forage species.

SUMMARY AND CONCLUSION

The results of this study indicate that DM yields of the Caucasian, Ganada, Plains, and WW-Spar cultivars differ significantly. Cultivar differences were consistent over plant parts. The Ganada and Caucasian cultivars had the lowest and highest yields, respectively. The Plains and WW-Spar DM yields were generally similar. The DM yield of whole plant, leaves, and stems increased with age; however, the yield of leaves increased at a slower rate than the yield of whole plant and stem fractions. The DM yield increases of all plant parts and all cultivars were quadratic in 1982 and linear in 1983. Yield components correlated negatively with IVDMD.

IVDMD varied among cultivars and were significantly affected by harvest date. Cultivar differences were consistent across plant parts. The Ganada and Caucasian cultivars had the highest and lowest IVDMD, respectively. Plains and WW-Spar had IVDMD values of similar magnitude and intermediate to those of Ganada and Caucasian. The IVDMD of whole plant, leaf, and stem components of all cultivars decreased curvilinearly with advancing maturity. However, the rate of decline of IVDMD with advancing maturity was greater in stems than in leaves for each cultivar.

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Table 1. prediction equations, coefficients of determination, and standard deviations for DM yield (kg ha^{-1}) and IVDMD ($g.kg^{-1}$) of old world bluestem cultivars.

Cultivar		Prediction equations†	R^2	SD
		Whole Plant DM Yield, 1982		
Plains	y=	$-1237.14 + 1095.10\ HD - 60.85\ HD^2$	.82	27.02
Caucasian	y=	$-187.88 + 782.82\ HD - 28.24\ HD^2$	.74	19.40
Ganada	y=	$-112.84 + 604.22\ HD - 31.41\ HD^2$	.78	21.44
WW-Spar	y=	$566.18 + 1009.27\ HD - 52.21\ HD^2$	.82	25.96
		Whole Plant DM Yield, 1983		
Plains	y=	$70.40 + 707.00\ HD - 31.92\ HD^2$	.85	22.41
Caucasian	y=	$594.00 + 487.45\ HD$	.84	25.36
Ganada	y=	$849.67 + 302.77\ HD$	.79	22.41
WW-Spar	y=	$278.56 + 425.01\ HD$	.87	22.55
		Leaf DM Yield, 1982		
Plains	y=	$-282.15 + 510.59\ HD - 38.48\ HD^2$	.71	17.25
Caucasian	y=	$266.76 + 277.80\ HD - 18.83\ HD^2$	.79	12.90
Ganada	y=	$100.85 + 265.68\ HD - 21.06\ HD^2$	.66	12.50
WW-Spar	y=	$91.25 + 432.84\ HD - 32.80\ HD^2$	.65	16.06
		Leaf DM Yield, 1983		
Plains	y=	$594.00 + 42.25\ HD$	.51	13.43
Caucasian	y=	$682.00 + 61.84\ HD$	.36	15.03
Ganada	y=	$439.41 + 20.67\ HD$	.25	10.73
WW-Spar	y=	$456.71 + 40.64\ HD$	.46	11.82
		Stem DM Yield, 1982		
Plains	y=	$-1001.92 + 625.57\ HD - 28.93\ HD^2$	.86	20.74
Caucasian	y=	$-490.22 + 543.39\ HD - 16.68\ HD^2$	.94	16.76
Ganada	y=	$-217.92 + 340.85\ HD - 12.45\ HD^2$	.79	18.14
WW-Spar	y=	$-671.61 + 607.80\ HD - 25.56\ HD^2$	.83	21.59
		Stem DM Yield, 1983		
Plains	y=	$98.25 + 295.29\ HD$	.88	18.50
Caucasian	y=	$-45.18 + 393.77\ HD$	.84	23.02
Ganada	y=	$279.24 + 274.55\ HD$	.82	20.07
WW-Spar	y=	$60.85 + 345.10\ HD$	.91	18.31

(Continued)

Table 1. (Continued)

Cultivar		Prediction equations†	R^2	SD
		IVDMD Whole Plants, 1982		
Plains	y=	600.00 - 38.30 HD + 1.60 HD^2	.92	1.43
Caucasian	y=	610.30 - 44.90 HD + 2.10 HD^2	.93	1.36
Ganada	y=	587.50 - 1.95 HD + 0.40 HD^2	.86	1.40
WW-Spar	y=	589.80 - 2.48 HD + 0.50 HD^2	.92	1.35
		IVDMD, 1983		
Plains	y=	687.30 - 48.90 HD + 2.20 HD^2	.95	1.34
Caucasian	y=	655.50 - 37.30 HD + 1.50 HD^2	.93	1.26
Ganada	y=	666.50 - 41.30 HD + 2.00 HD^2	.96	1.17
WW-Spar	y=	662.10 - 44.30 HD + 2.10 HD^2	.95	1.25
		IVDMD Leaves, 1982		
Plains	y=	603.90 - 31.30 HD + 1.20 HD^2	.91	1.36
Caucasian	y=	606.30 - 45.50 HD + 2.10 HD^2	.94	1.34
Ganada	y=	633.70 - 31.10 HD + 1.40 HD^2	.93	1.19
WW-Spar	y=	590.00 - 28.20 HD + 1.10 HD^2	.90	1.38
		IVDMD, 1983		
Plains	y=	652.30 - 21.40 HD + 0.40 HD^2	.93	1.23
Caucasian	y=	658.80 - 33.40 HD + 1.20 HD^2	.91	1.39
Ganada	y=	665.70 - 15.7 HD + 0.12 HD^2	.80	1.49
WW-Spar	y=	668.90 - 29.5 HD + 1.20 HD^2	.94	1.21
		IVDMD Stems, 1982		
Plains	y=	644.50 - 39.90 HD + 1.30 HD^2	.89	1.67
Caucasian	y=	629.30 - 54.30 HD + 2.90 HD^2	.93	1.40
Ganada	y=	590.70 - 15.40 HD + 0.40 HD^2	.90	1.43
WW-Spar	y=	637.70 - 37.50 HD + 1.10 HD^2	.93	1.46
		IVDMD, 1983		
Plains	y=	699.90 - 62.10 HD + 3.00 HD^2	.97	1.27
Caucasian	y=	637.00 - 33.00 HD + 1.00 HD^2	.96	1.11
Ganada	y=	694.46 - 58.00 HD + 3.10 HD^2	.97	1.20
WW-Spar	y=	689.40 - 64.70 HD + 3.70 HD^2	.96	1.28

†HD = harvest date (weeks 1-10).

Table 2. Simple correlations between dry matter yields and IVDMD of whole plants, leaves, and stems of four old world bluestem cultivars sampled weekly over a 10 week period during two years.

	Plant Part			
Cultivar	Whole Plants	Leaves	Stems	Heads
Plains	-.82**	-.59**	-.85**	-.44**
Caucasian	-.76**	-.62**	-.75**	-.54**
Ganada	-.72**	-.44**	-.71**	-.35**
WW-Spar	-.83**	-.51**	-.83**	-.51**

**P<.01.

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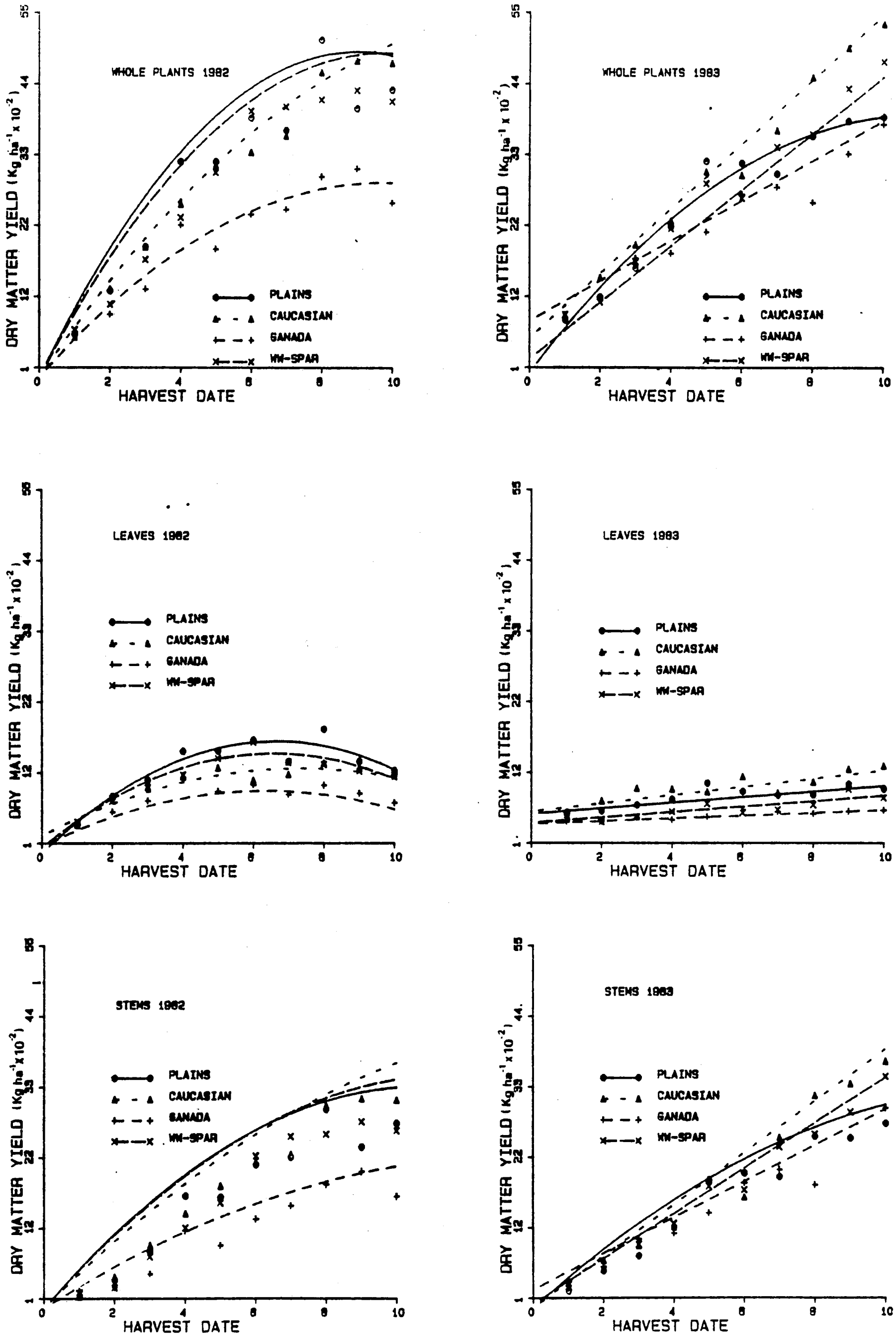

FIG. 1. DM yields of whole plant, leaves, and stems of four old world bluestem cultivars at ten harvest dates.

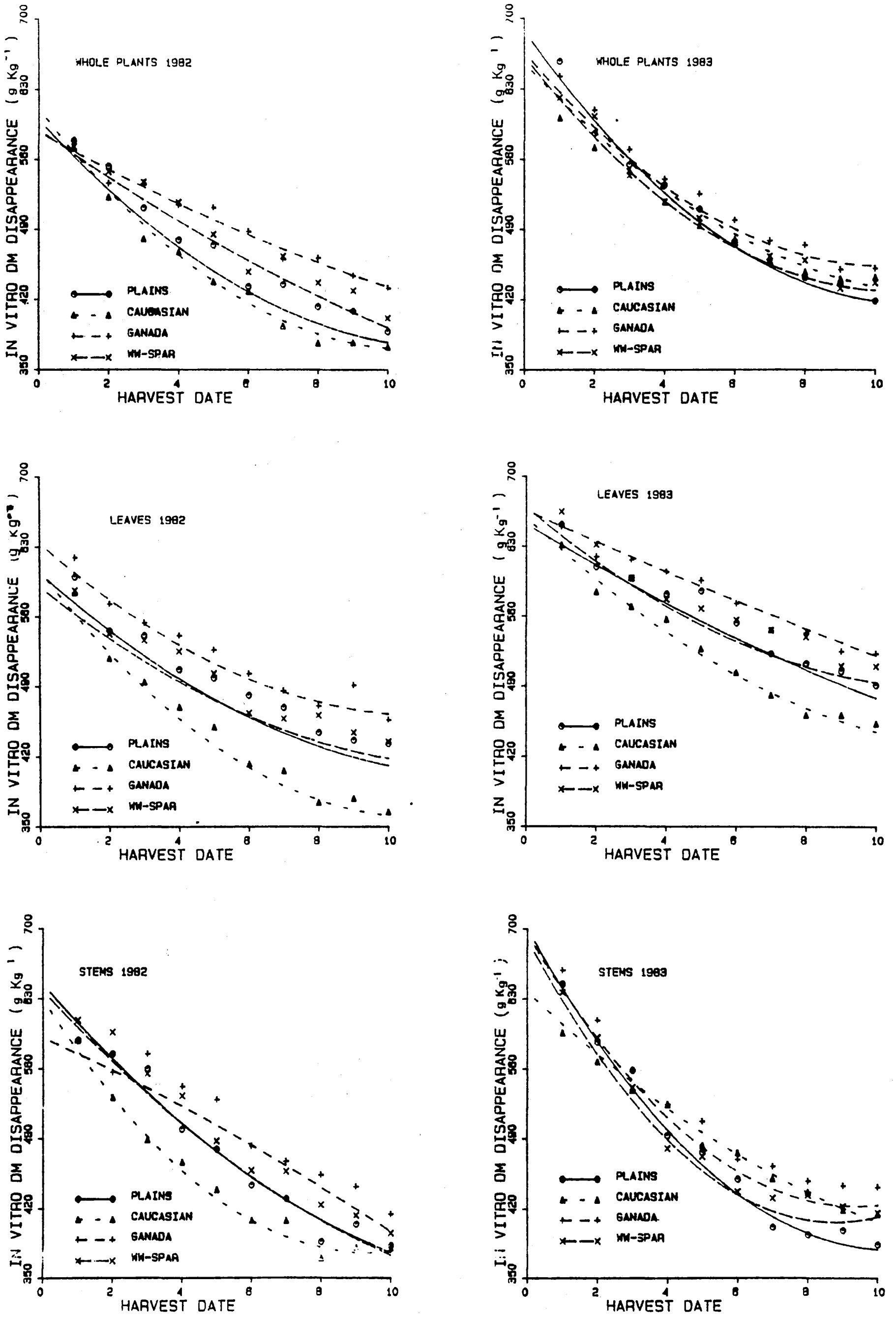

FIG. 2. In vitro dry matter disappearance of whole plant, leaves, and stems of four old world bluestem cultivars at ten harvest dates.

CHAPTER IV

CHEMICAL COMPOSITION OF FOUR OLD WORLD BLUESTEM CULTIVARS(*BOTHRIOCHLOA SPP*.,) AS AFFECTED BY PLANT PART AND MATURATION: RELATIONSHIP TO DIGESTIBILITY

ABSTRACT

Few data are available on the chemical composition of old world bluestem (*Bothriochloa Spp*.) forages despite their commercial use in the Great Plains. A study was conducted to determine the chemical composition of four such cultivars as affected by plant part and maturation, and ascertain the relationship between chemical components and in vitro dry matter disappearance (IVDMD). Field experiments were conducted on a Kirkland silt loam (Uderic Paleustoll) soil at the Agronomy Research Station, Stillwater, Oklahoma over a 2-year period, 1982-1983. The experimental design was a split-split plot in a randomized complete block, with 4 replications. Cultivars were main plots ; harvest dates and plant parts (leaf, stem, and whole plant), were sub and sub-sub plots, respectively. There were 10 harvest dates beginning 3 weeks after staging with an interval of one week between dates. Response variables were: neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), and crude protein (CP); all expressed as $g.kg^{-1}$ of forage.

There were significant cultivar differences for all the chemical characters except CP. Cultivar differences were generally consistent over plant parts. On a whole plant basis, Ganada had greater NDF and lower ADL concentrations than did the WW-Spar and Caucasian cultivars. The reverse was generaly true for Caucasian as compared to Ganada and WW-Spar. The NDF and ADL concentrations in Plains were generally similar to those in Ganada and Caucasian respectively. The Ganada cultivar had the lowest ADF concentrations in all plant parts in 1982 but there were no significant differences among cultivars for ADF concentration in 1983.

The NDF, ADF, and ADL concentrations of whole plant samples increased with maturation at respective mean rates of 2.8, 3.0, and 1.3 g kg^{-1} daily. Crude Protein declined 2.5 g.kg^{-1} daily with maturation at early stages and levelled off at the later stages. Similar trends occurred in leaf and stem portions, however the rate of change was greater in stems than in leaves. The mean NDF concentrations of whole plant samples ranged from 630 to 830 g.kg^{-1}. Cultivars had adequate CP for animal growth only during the first 3 harvest weeks. There were significant negative correlations between IVDMD and NDF, ADF, and ADL. CP concentrations were highly positively correlated with IVDMD in all plant parts across harvest dates but not at various stages of maturity except in leaves.

INTRODUCTION AND LITERATURE REVIEW

Old World bluestems (Bothriochloa Spp.) have been used extensively in the southern Great Plains as conservation and forage grasses. Their abundant seed production and adaptability have been well recognized (1, 8). The apparent superiority of these grasses in quality, production, and persistence under grazing to native grasses has have been reported (5).

The nutritive value of forages is important in plant breeding and animal production programs. However, this information sometimes can be misleading if only whole plant samples are analyzed. The parts of the plant i.e. leaves, stems, and heads differ in chemical and physical properties (10).

Van Soest (16) divided forage dry matter into two fractions, cell content (CC), containing readily digestible cellular solubles and neutral detergent fiber (NDF). The NDF is further divided into acid detergent soluble (ADS) containing water insoluble protein, and hemicellulose (HEM) and acid detergent fiber (ADF), containing essentially insoluble lignin, cellulose (CELL), and minerals.

Previous studies have shown that the crude protein (CP) and in vitro dry matter digestibility (IVDMD) of old world bluestems decline with increasing age (9, 14). However, trends for NDF, ADF, and acid detergent lignin (ADL) have not been established. A study by Voigt et al., (21) with weeping lovegrass Eragrostis curvula (Schrad) showed a decline in CP and CC from jointing to anthesis. CELL and lignin increased from jointing to anthesis while HEM decreased. Similar results with other grasses were reported by Armstrong et al. (4) and Crampton and Maynard (6).

Chemical components, unlike in vitro estimates of total dry matter digestibility, provide basic information on factors which influence forage intake and digestibility. When the cell wall constituent (CWC) fraction comprises more than 55% of forage dry matter, voluntary intake may be decreased (15). A significant correlation (r=0.73) was found between cell wall constituents (CWC) and intake of 126 grass samples (11). Slightly higher correlation was found between intake and CELL, holocellulose, and ADF. Van Soest et al. (19) also reported the correlations of various forage components with voluntary intake and digestibility for 187 forage of diverse species. Lignin and ADF were more closely related to digestibility than to intake, while the reverse was true for protein, CWC, CELL, and HEM. These correlation differences reflect the inherently different effects of feed chemical components upon intake and digestibility.

The objectives of this study were to: a)characterize the chemical composition of whole plants and component plant parts of four old world bluestem cultivars as affected by stage of maturity and b) ascertain the relationship between chemical components and IVDMD.

MATERIALS AND METHODS

This study was conducted during the 1982 and 1983 growing seasons using four Old World Bluestem cultivars ('Plains', 'Caucasian', 'Ganada', and 'WW-Spar') planted in a randomized complete block design with four replications. The plots were located on the Agronomy Research Station, Stillwater, OK on a Kirkland Silt Loam (Uderic Paleustoll) soil. Plots were 6 x 0.6m, each consisting of 5 rows spaced 15 cm apart. The test was seeded 28 July, 1980.

The nursery was staged at a height of 1.3 cm, 22 June, 1982 and 25 May, 1983. The plots were fertilized at a rate of 112 Kg N/ha soon after staging. Plots were then divided into ten .5 m^2 subplots. Harvest dates (1-10) were randomly assigned to subplots. Harvesting was started 3 weeks after staging and continued at weekly intervals. Subplots were clipped at a height of 1.3 cm from ground level. The total green weight was recorded for yield measurements and two subsamples were taken. The first subsample labelled "whole" was dried at 65°C for 7 days and used to convert subplot green yields to DM yields. The second subsample was frozen and subsequently separated into leaf, stem, and head (inflorescence) components. "Leaves" consisted of blades plus sheaths. After separation, the respective plant parts were dried in a forced draft oven at 65°C for 7 days. All dried samples were first ground through a 5 mm screen in a Willey Mill[1] and then through a 1 mm screen in a UDY Cyclone Mill[1] resulting in 20 to 30 g of ground forage. Chemical composition was determined for all except inflorescence samples.

Percent NDF, ADF, ADL, and CP were determined by near infrared reflectance (NIR) spectroscopy using a Neotec Model 6100 monochromator[1]. Sixty-four scans of each sample with monochromatic light in the near infrared region,from 1,100 to 2,500 nm, were averaged and stored on a Digital Equipment Corporation mini-computer PDP 11 L-03[1]. Seven hundred data points at 2.0 nm intervals were recorded for each sample.

The monochromator was calibrated for NDF and CP with 480 samples (50% of total), and for ADF and ADL with 240 forage samples (25% of the total samples including stems, leaves, and whole plants). Samples

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[1]Reference to a company or product name does not imply approval or recommendation of the product by the Oklahoma Agriculture Experiment Station to the exclusion of others which might be suitable.

used for laboratory analysis were obtained by random selection. Two replications were first selected, providing 240 samples for the NDF and CP determination yearly. Samples for the ADF and ADL were obtained by selection of one replication from the above two. Laboratory analyses were conducted in duplicate using the Kjeldahl procedures (2) for CP, and the various fiber analyses as outlined by Van Soest, (16, 18). Calibration of the monochromator was achieved using the operation computer software developed at the Pennsylvania State University (12). The software combined NIR reflectance data with the laboratory analyses, performed the necessary mathematical transformations (log 1/R, 1st and 2nd derivatives), and used a modified stepwise linear regression analysis to determine wavelengths suitable for predicting the unknowns. Seven calibration equations resulted and included 1 to 7 wavelengths and their regression coefficients for predicting forage chemical characters. On the basis of the R-square, bias, and standard error of prediction statistics, an equation was chosen to predict the NDF, ADF, ADL and CP from the reflectance spectra of the remaining samples.

An overall statistical analysis was first conducted on each chemical character using the ANOVA procedures for a split-split plot arrangement. Since year and plant part interactions occurred, data were then analyzed on a year and plant part basis to assess cultivar differences and the effects of harvest dates. Least significant difference test of treatment means backed by significant F-test was used to determine differences among cultivars (13). Orthogonal polynomials were used to partition the harvest dates and harvest dates x year sum-of-squares into linear, quadratic, and deviation from quadratic components. Chemical data were correlated with IVDMD to ascertain any significant relationship.

RESULTS AND DISCUSSION

Mean squares for cultivars, harvest dates, plant parts, years, and first and second order interactions involving all response variables were significant in the combined analysis of variance (Appendix Table B1). Interaction mean squares for cultivars x harvest dates x years and cultivars x harvest dates x years x plant parts were not significant for any response variable. The cultivar mean squares were nine or more times larger than any of the interaction mean squares that involved cultivars.

Whole Plants

Cultivar Differences. The only significant cultivar x harvest date interaction was for ADL in 1982 (Appendix Table B2). Thus, cultivar performance for these characters was consistent from stage to stage. The significant cultivar x harvest date interactions for ADL in 1982 were caused more by differences in magnitude of response than by differences in ranking.

Averaged over harvest dates, the Ganada cultivar had higher ($P<.05$) NDF concentrations than did the other three cultivars in 1983 (Table 1). In 1982, the NDF concentrations of WW-Spar were lower ($P<.05$) than those of Plains and Ganada. Mean NDF values ranged from 630 to 830 $kg.ha^{-1}$, well above the 550 $g.kg^{-1}$ level where voluntary intake may be adversely effected (15). Neutral detergent fibers values obtained in this study were similar in magnitude to those reported by Horn and

Jackson (9).

The ADF concentrations were lowest for Ganada in 1982, but similar for all cultivars in 1983 and averaged 447 $g.kg^{-1}$ (Table 1). Overall values ranged from 370 $g.kg^{-1}$ at harvest week 1 to 475 $g.kg^{-1}$ at harvest week 10. The inconsistent year differences in NDF and ADF concentrations among cultivars suggests that age of tissue at cutting may be less important for these characters than the climatic conditions under which the forage is cut.

Differences in ADL concentration among cultivars were small and consistent over years (Table 1). The Caucasian cultivar consistently had higher ADL concentrations than Ganada and WW-Spar. This pattern is likely related to the lower digestibility of Caucasian bluestem (Chap III). The fact that Ganada had the highest NDF concentration and the lowest ADF and ADL concentrations suggests that the increase in NDF was primarily due to higher hemicellulose (HEM) content.

Unlike NDF, ADF and ADL, CP differences among cultivars were not significant. The CP values averaged over cultivars were 77 and 66 $g.kg^{-1}$, respectively, in 1982 and 1983. Overall values ranged from 138 $g.kg^{-1}$ at harvest week 1 to 36 $g.kg^{-1}$ at harvest week 10 (Appendix Table A6). Feed intake or digestibility may be depressed when CP of forage is below 70 $g.kg^{-1}$ (20). In this case the cultivars had adequate CP for animal growth only during the first 3 harvest weeks (Appendix Table A6).

Effect of Harvest Dates. Fig. 1 illustrates changes in NDF, ADF, and ADL concentrations with maturation. Cultivar trends were similar, generally fitting quadratic equations. The exception of linear equations fitting NDF and ADL data in 1982 (Table 3) is probably due to both environmental effects on growth and initial concentrations of these characters in the plants.

NDF increased (P<.01) with maturation at the rate of 1.20 $g.kg^{-1}$ daily in 1982. The rate of change was greatest in Caucasian and WW-Spar (1.50 $g.kg^{-1}$ daily) and lowest in Ganada (.80 $g.kg^{-1}$ daily). Our results with Caucasian are in agreement with earlier findings (3). However, in 1983 the initial rates of increase in NDF were drastic and inconsistent. A mean rate increase of 4.50 $g.kg^{-1}$ daily was recorded for all cultivars, ranging from 5.30 $g.kg^{-1}$ daily for Ganada and WW-Spar to 2.80 $g.kg^{-1}$ daily for Caucasian and Plains.

The effect of harvest date on ADF concentrations was similar in trends and rates of change to those just discussed for NDF. The respective mean increases were 2.20 and 4.00 $g.kg^{-1}$ daily in 1982 and 1983. The rate of change differences between cultivars were not consistent over years. This inconsistency, plus the magnitude of rate of change differences between years, again confirm the sensitivity of NDF and ADF to environmental conditions.

Results for ADL also revealed an average increase of 1.30 $g.kg^{-1}$ daily in 1983. These results agree with previously reported data on lovegrasses (21). As in NDF and ADF, the rates of change were lower in 1982 than in 1983 (Table 3) and averaged only .33 $g.kg^{-1}$ daily.

Crude protein concentrations declined 2.50 $g.kg^{-1}$ daily both years (Fig 2). There was a more rapid decline at the early sampling dates that agreed with reports by Farrington (7) on lovegrasses.

Separated Portions

The occurrence of cultivar x harvest date interactions in leaf and stem data (Appendix Tables B4-B7) complicates a discussion of the NDF and ADF results. However, certain differences and trends clearly emerged and will be briefly dicussed for each chemical component.

<u>NDF</u>. For both stems and leaves, the NDF concentrations of Ganada Plains tended to be higher than those of the WW-Spar cultivar (Appendix Table A3). Linear equations best described the data in 1982, with respective mean rates of increase of 0.40 and 1.50 $g.kg^{-1}$ daily (Tables 4, 5). In 1983 quadratic equations satisfactorily fit the data for stems while significant deviations from this trend occurred in leaf segments (Appendix Table B12 and B13). The overall data revealed that stems contained approximately 120 $g.kg^{-1}$ more NDF than Leaves.

<u>ADF</u>. The ADF concentrations averaged over cultivars increased approximately .80 and 1.60 $g.kg^{-1}$ daily in leaves and stems respectively (Tables 4, 5). Cultivars were different only in 1982 and 1983 for stems and leaves respectively with a tendency for Caucasian to be highest and Ganada to be lowest.

<u>ADL</u>. The ADL concentrations in leaves and stems also increased significantly ($P<.01$) with advancing maturity. The mean rate of increase in 1982 was slower in leaves (.19 $g.kg^{-1}$ daily) than in stems (.51 $g.kg^{-1}$ daily). As in whole plant samples, the data fit first and second order polynomial equations in 1982 and 1983, respectively (Tables 3, 4). Deviations from quadratic response were negligeable. Cultivar differences were small and consistent over years and

plant parts. The Caucasian and Plains cultivars consistently had the highest ADL concentrations while Ganada had the lowest (Table 2). Overall, stems contained 330 $g.kg^{-1}$ more ADL than leaves.

CP. The four cultivars followed the same general decrease in concentration of CP with increasing maturity (Fig. 2). The data satisfactorilly fit a quadratic equation for both stems and leaves, with similar mean rates of decline of 2.80 $g.kg^{-1}$ daily (Tables 4, 5). Leaf samples had adequate CP for animal growth through harvest week 8, and stem samples during the first 2 harvest weeks only. CP varied significantly ($P<.05$) between Caucasian and WW-Spar only in 1982 in stem data. Leaves had twice the protein concentration of stems.

Interrelationships Between Chemical Parameters and *In vitro* Dry Matter Disappearance (IVDMD).

Correlation coefficients calculated from cultivar means for each plant part are shown in Table 6. The IVDMD values used here are those reported for the same cultivars and plant parts in CHAP III. NDF, ADF, and ADL constituents were negatively correlated with IVDMD. This inverse relationship between ADL, ADF, and IVDMD is consistent with reports for many other forage species. Of these traits, NDF was least highly correlated and ADL was most highly correlated with IVDMD. The high ADL correlations in Caucasian are consistent with its high lignin content. Ganada had the lowest ADL concentration in leaves and whole plants but not in stems. High CP was associated with high IVDMD. Correlations coefficients were highest in leaves.

Correlation coefficients calculated from harvest date means (Table 7) revealed that high IVDMD was most closely associated with low ADF and ADL in leaves and in stems but not in whole plants. No correlation existed between NDF and IVDMD at various stages of maturity.

Significant positive correlations between CP and IVDMD occurred most often in leaves and were usually not significant in stems and whole plants. This significant correlation of leaf CP with IVDMD may be associated with the high CP content of that fraction.

In summary, the NDF, ADF and ADL concentrations of old world bluestem cultivars increased significnatly with advancing maturity. Mean rates of increase were generally faster in stems than in leaves. Crude protein concentrations decreased significantly with maturation at early stages of maturity and then levelled off at later stages.

Except for CP, there were significant differences between cultivars. However, while the extent of and the rate of change in chemical traits with maturation differs among cultivars, the magnitude of the differences is not great.

Lignin has long been regarded as the main factor limiting the digestibility of forages. The involvement of this "negative index of quality" with CELL and HEM in the different plant parts may be the main factor behind the chemical composition differences of these old world bluestem grasses.

Across harvest dates, low NDF, ADF and ADL and high CP were associated with high IVDMD. Acid detergent lignin was most strongly correlated and NDF was least stongly correlated with IVDMD.

Comparisons within individual maturity stages showed that low ADF and ADL were associated with high IVDMD in leaves and stems only. Crude protein was positively correlated with IVDMD in leaves only.

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List of Tables

Table 1. Neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) concentrations of whole plant samples of four old world bluestem cultivars during 2 years (means of 10 harvest dates).

	NDF		ADF		ADL	
Cultivars	1982	1983	1982	1983	1982	1983
	g.Kg^{-1}					
Plains	747.0[a]	776.9*[a]	438.8[a]	446.3[a]	58.9[a]	56.1[a]
Caucasian	738.6[ab]	768.2[a]	445.8[ab]	453.7[a]	58.9[a]	58.0[b]
Ganada	748.5[a]	795.0[b]	427.2[c]	442.2[a]	51.8[b]	56.4[a]
WW-Spar	727.8[b]	772.0[a]	431.4[ac]	445.2[a]	54.0[b]	57.2[a]

*Values within a column followed by the same letter are not different (P>.05) by LSD Test.

Table 2. Acid detergent lignin (ADL), and crude protein (CP) concentrations in leaf and stem samples of four old world bluestem cultivars during 2 years (means of 10 harvest dates).

	Leaves				Stems			
	ADL		CP		ADL		CP	
Cultivars	1982	1983	1982	1983	1982	1983	1982	1983
	g Kg^{-1}							
Plains	50.14^{a*}	43.21^{a}	102.56^{a}	94.64^{a}	67.55^{a}	69.34^{a}	56.35^{a}	43.28^{a}
Caucasian	46.09^{ab}	45.01^{ab}	84.04^{a}	79.97^{a}	70.00^{a}	67.46^{a}	44.58^{ab}	37.40^{a}
Ganada	43.22^{b}	41.62^{ac}	96.71^{a}	97.60^{a}	58.08^{b}	65.43^{a}	49.35^{a}	40.37^{a}
WW-Spar	46.25^{ab}	40.89^{ac}	104.33^{a}	98.27^{a}	63.37^{ab}	68.34^{a}	62.99^{ac}	43.45^{a}

*Values within a column followed by the same letter are not different ($P \geq .05$) by LSD Test.

Table 3. Prediction equations, coefficients of determination, and standard deviations for chemical components in whole plant samples of four old world bluestem cultivars.

Cultivar		Prediction equations†	R^2	SD
		Neutral Detergent Fiber, 1982		
Plains	y=	709.2 + 7.6 HD	.86	.98
Caucasian	y=	685.8 + 10.2 HD	.73	1.38
Ganada	y=	723.0 + 5.6 HD	.52	1.34
WW-Spar	y=	687.3 + 10.2 HD	.33	2.25
		Acid Detergent Fiber, 1982		
Plains	y=	382.6 + 9.5 HD	.82	1.19
Caucasian	y=	$348.5 + 25.9\ HD - 1.3\ HD^2$	.81	1.35
Ganada	y=	$357.6 + 18.4\ HD - 1.0\ HD^2$	.60	1.38
WW-Spar	y=	399.2 + 4.3 HD	.11	2.25
		Acid Detergent Lignin, 1982		
Plains	y=	42.4 + 2.6 HD	.72	.77
Caucasian	y=	38.3 + 3.7 HD	.83	.71
Ganada	y=	47.0 + 0.8 HD	.28	.71
WW-Spar	y=	40.1 + 2.1 HD	.50	.86
		Crude Protein, 1982		
Plains	y=	$157.1 - 24.3\ HD + 1.2\ HD^2$	.94	.96
Caucasian	y=	$170.7 - 31.7\ HD + 1.8\ HD^2$	.95	.93
Ganada	y=	$175.9 - 26.3\ HD + 1.3\ HD^2$	.92	1.06
WW-Spar	y=	$156.7 - 20.8\ HD + 0.9\ HD^2$	.88	1.18
		Neutral Detergent Fiber, 1983		
Plains	y=	$666.2 + 32.1\ HD - 1.6\ HD^2$	.91	1.20
Caucasian	y=	$667.8 + 30.5\ HD - 1.7\ HD^2$	.81	1.77
Ganada	y=	$683.5 + 39.3\ HD - 2.4\ HD^2$	.89	1.43
WW-Spar	y=	$647.6 + 39.7\ HD - 2.3\ HD^2$	.86	1.39
		Acid Detergent Fiber, 1983		
Plains	y=	$314.8 + 42.0\ HD - 2.4\ HD^2$	.95	1.10
Caucasian	y=	$354.4 + 36.1\ HD - 2.2\ HD^2$	.91	1.16
Ganada	y=	$334.9 + 37.6\ HD - 2.3\ HD^2$	.89	1.22
WW-Spar	y=	$319.5 + 39.6\ HD - 2.4\ HD^2$	.92	1.16

(Continued)

Table 3. (Continued)

Cultivar		Prediction equations†	R^2	SD
		Acid Detergent Lignin, 1983		
Plains	y=	$20.0 + 10.3\ HD - 0.5\ HD^2$	.95	.55
Caucasian	y=	$29.3 + 8.8\ HD - 0.5\ HD^2$	.91	.59
Ganada	y=	$26.2 + 9.7\ HD - 0.6\ HD^2$	.93	.56
WW-Spar	y=	$27.2 + 9.3\ HD - 0.5\ HD^2$	.93	.56
		Crude Protein, 1983		
Plains	y=	$155.7 - 23.7\ HD + 1.1\ HD^2$	.96	.84
Caucasian	y=	$143.0 - 25.3\ HD + 1.4\ HD^2$	.92	.96
Ganada	y=	$161.8 - 28.6\ HD + 1.6\ HD^2$	.95	.91
WW-Spar	y=	$144.2 - 23.8\ HD + 1.3\ HD^2$	.93	.94

†Y = concentration ($g.kg^{-1}$), HD = harvest date (weeks 1-10).

Table 4. Prediction equations, coefficients of determination, and standard deviations for chemical components in leaf samples of four old world bluestem cultivars.

Cultivar		Prediction equations†	R^2	SD
		Neutral Detergent Fiber, 1982		
Plains	y=	$684.2 + 13.3\ HD - 1.0\ HD^2$	.42	1.14
Caucasian	y=	$680.3 + 1.7\ HD$	.36	1.00
Ganada	y=	$689.7 + 4.0\ HD$	.26	1.44
WW-Spar	y=	$704.7 + 2.6\ HD$	.29	1.47
		Acid Detergent Fiber, 1982		
Plains	y=	$349.9 + 16.7\ HD - 1.1\ HD^2$	.67	1.77
Caucasian	y=	$369.9 + 2.8\ HD$	.32	1.20
Ganada	y=	$364.4 + 4.5\ HD$	.35	1.44
WW-Spar	y=	$346.0 + 18.9\ HD - 1.4\ HD^2$	.30	1.57
		Acid Detergent Lignin, 1982		
Plains	y=	$43.9 + 1.2\ HD$	.59	.59
Caucasian	y=	$40.2 + 1.5\ HD$	.64	.61
Ganada	y=	$36.3 + 1.3\ HD$	.30	.81
WW-Spar	y=	$43.9 + 1.3\ HD$	.45	.75
		Crude Protein, 1982		
Plains	y=	$170.4 - 19.8\ HD + 0.80\ HD^2$	.93	.89
Caucasian	y=	$172.5 - 27.3\ HD + 1.50\ HD^2$	.94	.81
Ganada	y=	$200.9 - 27.7\ HD + 1.40\ HD^2$	.94	.79
WW-Spar	y=	$183.9 - 26.6\ HD + 1.40\ HD^2$	.93	1.08
		Neutral Detergent Fiber, 1983		
Plains	y=	$690.7 + 9.2\ HD - .6\ HD^2$	.43	1.22
Caucasian	y=	$693.2 - 3.8\ HD + .3\ HD^2$	.22	1.13
Ganada	y=	$703.5 - 1.6\ HD + .3\ HD^2$	.15	1.11
WW-Spar	y=	$666.7 + 2.9\ HD - .2\ HD^2$	.15	1.33
		Acid Detergent Fiber, 1983		
Plains	y=	$324.5 + 18.7\ HD - .9\ HD^2$	.89	1.17
Caucasian	y=	$332.4 + 13.2\ HD - .6\ HD^2$	.94	.75
Ganada	y=	$339.7 + 7.1\ HD$	.87	1.44
WW-Spar	y=	$329.3 + 11.6\ HD - .5\ HD$	.81	.98

(Continued)

Table 4. (Continued)

Cultivar		Prediction equations†	R^2	SD
		Acid Detergent Lignin, 1983		
Plains	y=	$22.9 + 5.0\ HD - 0.2\ HD^2$	.89	.54
Caucasian	y=	$28.0 + 4.5\ HD - 0.2\ HD^2$	.91	.49
Ganada	y=	$29.5 + 2.1\ HD$	.77	.81
WW-Spar	y=	$25.2 + 4.9\ HD - 0.2\ HD^2$	.90	.53
		Crude Protein, 1983		
Plains	y=	$141.7 + 9.1\ HD$	.91	.98
Caucasian	y=	$154.9 + 21.1\ HD + 1.0\ HD^2$	.95	.68
Ganada	y=	$170.1 - 14.1\ HD + 0.3\ HD^2$	.95	.84
WW-Spar	y=	$146.3 - 15.7\ HD + 0.6\ HD^2$	.93	.91

†Y = concentration ($g.kg^{-1}$), HD = harvest date (weeks 1-10).

Table 5. Prediction equations, coefficients of determination, and standard deviations for chemical components in stem samples of four old world bluestem cultivars.

Cultivar		Prediction equations[†]	R^2	SD
		Neutral Detergent Fiber, 1982		
Plains	y=	718.4 + 11.3 HD	.87	1.17
Caucasian	y=	683.3 + 30.6 HD - 1.5 HD^2	.89	1.26
Ganada	y=	734.3 + 9.3 HD	.77	1.27
WW-Spar	y=	656.9 + 20.2 HD	.50	2.57
		Acid Detergent Fiber, 1982		
Plains	y=	372.8 + 31.1 HD - 1.8 HD^2	.89	1.07
Caucasian	y=	377.6 + 36.7 HD - 2.2 HD^2	.93	1.06
Ganada	y=	399.1 + 18.5 HD - 0.9 HD^2	.75	1.22
WW-Spar	y=	464.1 + 7.5 HD - 1.1 HD^2	.19	2.48
		Acid Detergent Lignin, 1982		
Plains	y=	43.7 + 3.8 HD	.37	1.26
Caucasian	y=	24.3 + 16.9 HD - 1.2 HD^2	.55	1.19
Ganada	y=	44.7 + 2.7 HD	.73	.73
WW-Spar	y=	37.7 + 4.1 HD	.80	.81
		Crude Protein, 1982		
Plains	y=	115.1 - 17.5 HD + .8 HD^2	.93	.89
Caucasian	y=	122.9 - 25.8 HD + 1.5 HD^2	.95	.81
Ganada.	y=	116.9 - 18.6 HD + 1.0 HD^2	.94	.79
WW-Spar	y=	129.8 - 19.8 HD + 0.9 HD^2	.89	1.08
		Neutral Detergent Fiber, 1983		
Plains	y=	662.8 + 48.4 HD - 2.9 HD^2	.93	1.27
Caucasian	y=	695.6 + 39.1 HD - 2.3 HD^2	.91	1.23
Ganada	y=	717.7 + 40.4 HD - 2.5 HD^2	.84	1.39
WW-Spar	y=	664.2 + 51.9 HD - 3.3 HD^2	.92	1.26
		Acid Detergent Fiber, 1983		
Plains	y=	327.1 + 49.7 HD - 2.9 HD^2	.95	1.15
Caucasian	y=	401.7 + 37.1 HD - 2.1 HD^2	.95	1.04
Ganada	y=	364.6 + 40.7 HD - 2.7 HD^2	.85	1.32
WW-Spar	y=	326.6 + 51.2 HD - 3.3 HD^2	.91	1.28

(Continued)

Table 5. (Continued)

Cultivar		Prediction equations†	R^2	SD
		Acid Detergent Lignin, 1983		
Plains	y=	$27.5 + 12.8\ HD - .7\ HD^2$	.97	.53
Caucasian	y=	$37.3 + 9.3\ HD - .5\ HD^2$	.96	.49
Ganada	y=	$35.6 + 10.9\ HD - .7\ HD^2$	.92	.58
WW-Spar	y=	$32.7 + 12.2\ HD - .8\ HD^2$	.93	.58
		Crude Protein, 1983		
Plains	y=	$104.7 - 18.2\ HD + .9\ HD^2$	.95	.77
Caucasian	y=	$102.6 - 20.4\ HD + 1.2\ HD^2$	.95	.74
Ganada	y=	$104.1 - 20.0\ HD + 1.2\ HD^2$	.95	.75
WW-Spar	y=	$97.5 - 18.9\ HD + 1.1\ HD^2$	.94	.78

†Y = concentration ($g.kg^{-1}$), HD = harvest date (weeks 1-10).

Table 6. Simple correlations between chemical components and in vitro dry matter disappearance across harvest dates in whole plant, leaf and stem samples. Mean of 2 years.

Plant Part	Cultivar	Chemical Component			
		NDF	ADF	ADL	CP
Whole Plant	Plains	-.70**	-.85**	-.82**	.87**
	Caucasian	-.55**	-.75**	-.84**	.82**
	Ganada	.53**	-.77**	-.72**	.84**
	WW-Spar	-.57**	-.56**	-.78**	.87**
Leaves	Plains	-.41**	-.80**	-.82**	.74**
	Caucasian	.009	-.70**	-.74**	.80**
	Ganada	-.44**	-.74**	-.68**	.78**
	WW-Spar	-.52**	-.66**	-.82**	.74**
Stems	Plains	-.86**	-.94**	-.75**	.88**
	Caucasian	-.68**	-.85**	-.72**	-.84**
	Ganada	-.73**	-.87**	-.85**	.87**
	WW-Spar	-.72**	-.54**	-.87**	.89**

**P<.01. *P<.05. N=80.

Table 7. Simple correlations between chemical components and in vitro dry matter disappearance at each 10 harvest dates in whole plant, leaf and stem samples. Mean of four cultivars and 2 years.

Plant Part	Maturity Stage (weeks)	Chemical Component			
		NDF	ADF	ADL	CP
Whole Plant	1	-.12	-.77	-.82**	.13
	2	.06	-.32	-.66**	.08
	3	.44*	.12	.16	.19
	4	.20	-.12	-.29	.30
	5	.48**	.09	-.21	.10
	6	.54**	.50**	.12	-.13
	7	.18	-.27	-.25	.49**
	8	-.01	-.43*	-.40*	.37*
	9	.33	-.09	-.25	.20
	10	.28	-.09	-.34	.18
Leaves	1	.33	-.54**	-.81**	-.21
	2	-.27	-.81**	-.79**	.11
	3	.40*	-.69**	-.56**	.36*
	4	.07	-.65**	-.53**	.47**
	5	.13	-.39*	-.60**	.63**
	6	-.002	-.08	-.53**	-.43*
	7	-.03	-.43*	-.49**	.70**
	8	-.07	-.19	-.38*	.41*
	9	.19	.24	-.28	.29
	10	-.06	-.09	-.09	.37*
Stems	1	-.07	-.30	-.66**	-.05
	2	-.13	-.20	-.21	.28
	3	.04	-.53**	-.31	.24
	4	-.30	-.75**	-.73**	.52**
	5	-.25	-.73**	-.77**	.28
	6	-.10	-.55**	-.59**	.29
	7	-.36*	-.57**	-.64**	.33
	8	-.16	-.61	-.16	.17
	9	-.16	-.55**	-.59**	.39*
	10	.24	-.27	.08	.06

**P<.01. *P<.05. N=32.

LIST OF FIGURES

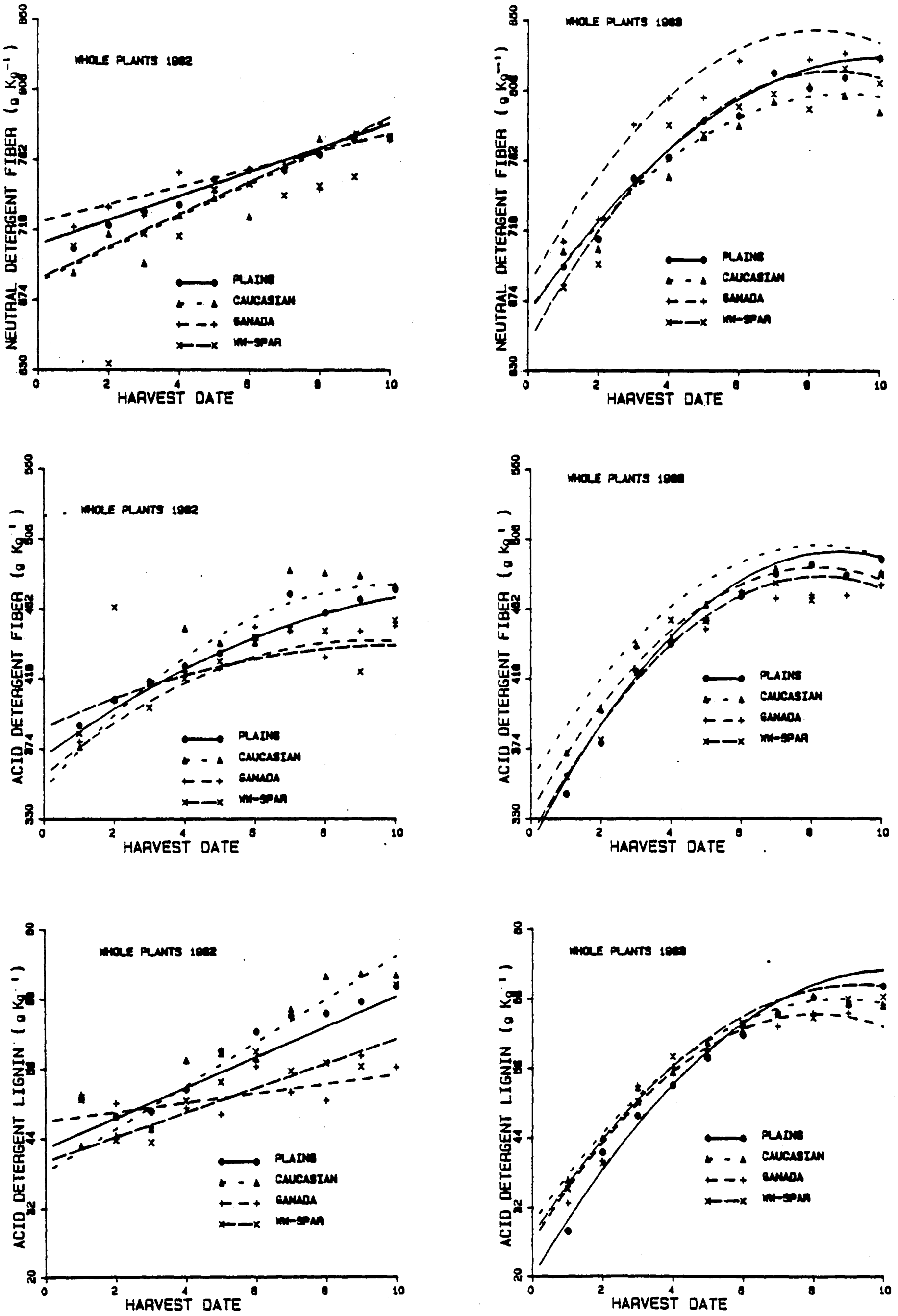

FIG. 1. Neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL) concentrations of whole plant samples of four old world bluestem cultivars in 1982 and 1983.

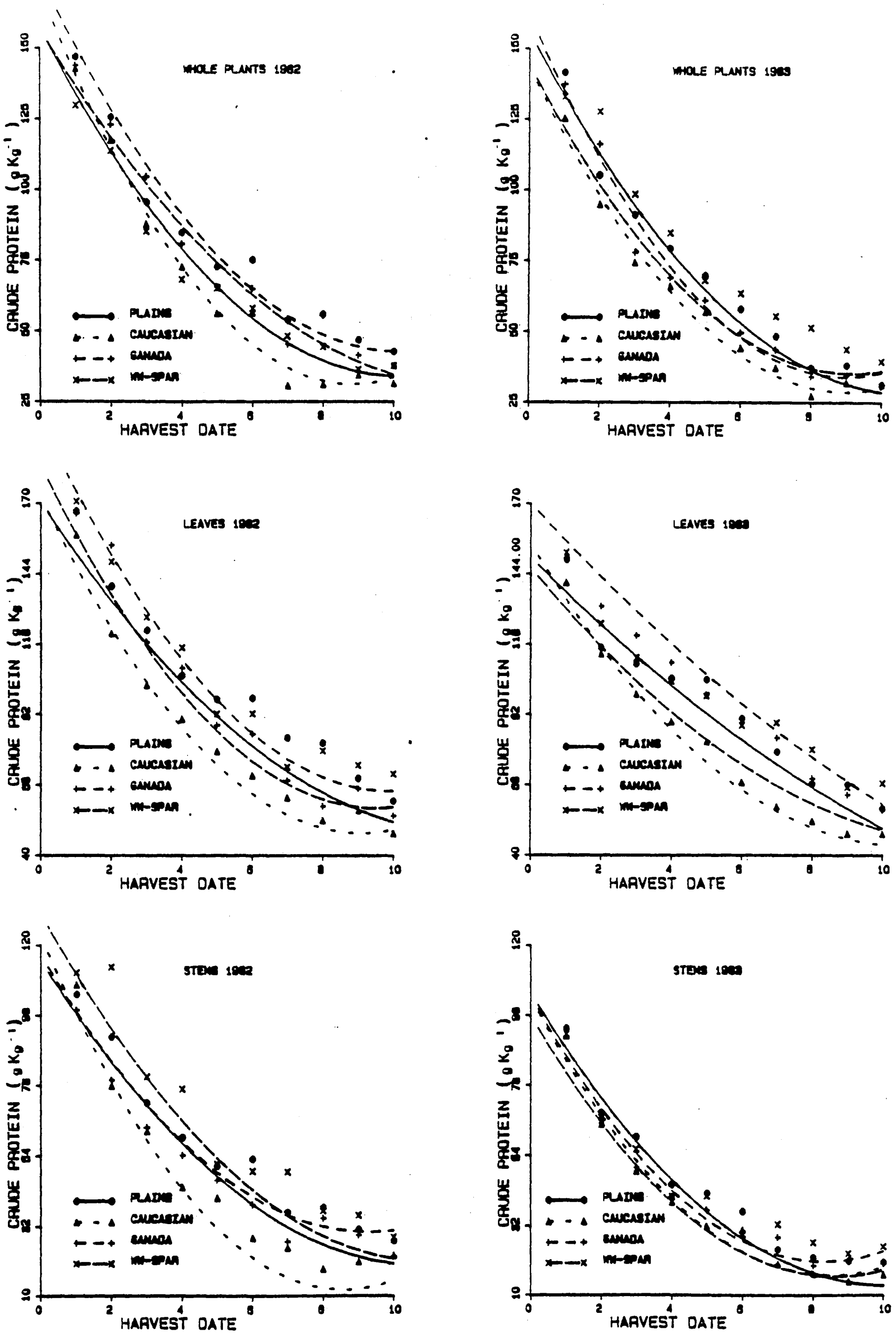

FIG. 2. Crude protein concentrations of whole plant, leaf, and stem samples of four old world bluestem cultivars in 1982 and 1983.

APPENDIX A

Listings of means, for cultivars DM yield, and quality components by plant part and by harvest date.

List of Tables

Table A1. Dry matter yields of whole plants and component parts of four old world bluestem cultivars as affected by year and stage of maturity.

		Plant Part															
	Harvest	Whole Plants				Leaves				Stems				Inflorescenses			
Year	No.	Plains	Caucasian	Ganada	WW-Spar	Plains	Caucasian	Ganada	WW-Spar	Plains	Caucasian	Ganada	WW-Spar	Plains	Caucasian	Ganada	WW-Spar
		Kg ha^{-1}															
1982	1	647	600	686	716	454 (70)	425 (71)	421 (62)	476 (67)	192 (30)	175 (29)	266 (38)	240 (33)	0 (0)	0 (0)	0 (0)	0 (0)
	2	1300	1327	950	1100	852 (66)	854 (64)	620 (65)	784 (12)	426 (32)	473 (36)	323 (34)	316 (28)	21 (2)	0 (0)	7 (1)	0 (0)
	3	1969	1968	1326	1775	1102 (56)	1006 (51)	791 (80)	989 (56)	867 (44)	962 (49)	524 (39)	786 (44)	0 (0)	0 (0)	11 (1)	0 (0)
	4	3256	2611	2299	2412	1545 (48)	1166 (45)	1111 (49)	1186 (50)	1712 (52)	1445 (55)	1182 (50)	1226 (50)	0 (0)	0 (0)	6 (0)	0 (0)
	5	3254	3198	1933	3095	1550 (48)	1290 (40)	936 (48)	1439 (47)	1692 (52)	1864 (58)	956 (50)	1613 (52)	12 (0)	44 (1)	42 (2)	43 (1)
	6	3921	3399	2460	4025	1715 (44)	1097 (32)	1035 (42)	1679 (41)	2182 (55)	2226 (66)	1363 (55)	2317 (58)	24 (0)	77 (2)	63 (3)	28 (1)
	7	3729	3643	2535	4090	1386 (37)	1193 (33)	884 (35)	1376 (34)	2296 (61)	2333 (64)	1567 (62)	2614 (64)	47 (1)	117 (3)	83 (3)	99 (2)
	8	5087	4603	3028	4193	1874 (37)	1366 (30)	1026 (34)	1343 (32)	3017 (60)	3070 (67)	1885 (62)	2642 (63)	197 (4)	167 (4)	116 (4)	207 (5)
	9	4061	4780	3149	4336	1391 (35)	1282 (27)	901 (28)	1240 (29)	2451 (60)	3182 (67)	2082 (66)	2835 (65)	220 (5)	316 (7)	166 (5)	261 (6)
	10	4341	4742	2636	4167	1243 (29)	1201 (26)	759 (29)	1155 (28)	2810 (65)	3160 (66)	1707 (65)	2696 (65)	289 (7)	382 (8)	171 (6)	315 (8)
	$\bar{X}$	3157	3087	2100	2991	1311 (47)	1088 (42)	848 (45)	1167 (46)	1764 (51)	1889 (56)	1185 (52)	1729 (52)	81 (2)	110 (3)	67 (3)	95 (2)
1983	1	856	936	860	946	604 (71)	613 (66)	470 (55)	569 (60)	253 (29)	323 (34)	390 (45)	377 (40)	0 (0)	0 (0)	0 (0)	0 (0)
	2	1206	1508	1171	1134	632 (53)	787 (52)	473 (42)	469 (41)	553 (45)	717 (47)	610 (52)	586 (52)	21 (2)	4 (0)	88 (7)	79 (7)
	3	1643	1999	1792	1744	721 (44)	973 (51)	531 (30)	546 (32)	784 (48)	942 (45)	1042 (58)	964 (55)	138 (8)	84 (4)	219 (12)	233 (13)
	4	2274	2362	1864	2243	806 (35)	964 (41)	498 (28)	623 (28)	1229 (54)	1229 (52)	1135 (60)	1288 (57)	239 (11)	168 (7)	231 (12)	332 (15)
	5	3264	3103	2193	2932	1054 (32)	921 (30)	543 (25)	745 (26)	1945 (59)	1948 (63)	1447 (66)	1857 (63)	266 (8)	234 (8)	203 (9)	330 (11)
	6	3233	3050	2761	2710	927 (28)	1152 (38)	651 (23)	608 (23)	2054 (64)	1694 (56)	1910 (69)	1802 (66)	252 (8)	204 (7)	200 (7)	300 (11)
	7	3072	3728	2871	3482	870 (28)	910 (24)	624 (22)	653 (19)	1997 (65)	2592 (69)	2107 (73)	2451 (71)	205 (7)	226 (6)	140 (5)	378 (10)
	8	3646	4533	2640	3677	882 (24)	1069 (24)	589 (23)	727 (20)	2607 (72)	3229 (71)	1874 (70)	2646 (72)	158 (4)	235 (5)	176 (7)	304 (8)
	9	3870	4968	3375	4361	1038 (26)	1267 (25)	629 (19)	964 (22)	2582 (67)	3408 (69)	2591 (77)	2980 (68)	250 (6)	293 (6)	155 (5)	418 (9)
	10	3934	5325	3826	4765	966 (24)	1313 (25)	642 (17)	834 (18)	2808 (72)	3753 (70)	3044 (79)	3525 (74)	160 (4)	259 (5)	140 (4)	405 (8)
	$\bar{X}$	2700	3151	2335	2799	850 (37)	997 (38)	565 (28)	674 (29)	1681 (58)	1984 (58)	1615 (65)	1847 (62)	169 (6)	171 (5)	155 (7)	278 (9)

Table A2. Mean in vitro dry matter disappearance (IVDMD) of whole plant, leaf and stem samples of four old world bluestem cultivars as affected by date of harvest.

Plant Part	Harvest Date	Plains 1982	Plains 1983	Plains Avg.	Caucasian 1982	Caucasian 1983	Caucasian Avg.	Ganada 1982	Ganada 1983	Ganada Avg.	WW-Spar 1982	WW-Spar 1983	WW-Spar Avg.
		$g\ Kg^{-1}$											
Whole Plant	1	578.90	657.38	618.14	571.60	601.10	586.35	578.60	642.50	610.55	572.73	621.30	597.01
	2	553.05	585.93	569.49	522.05	571.38	546.71	536.25	609.00	572.63	547.90	602.70	575.30
	3	511.43	554.40	532.91	480.63	548.08	514.35	536.18	569.73	552.95	537.18	543.83	540.50
	4	479.53	534.65	507.09	467.38	517.20	492.29	514.20	540.33	527.26	517.35	517.53	517.44
	5	474.25	510.63	492.44	437.55	493.95	465.75	511.75	525.73	518.74	485.45	501.65	493.55
	6	432.83	475.68	454.25	427.93	480.05	453.99	487.93	499.28	493.60	447.73	476.65	462.19
	7	435.15	455.48	445.31	393.48	462.05	427.76	460.20	478.75	469.48	463.33	463.23	463.28
	8	412.78	442.08	427.43	375.98	447.38	411.68	461.45	474.40	467.93	436.73	459.03	447.88
	9	408.23	435.56	421.89	376.85	440.50	408.68	443.53	450.33	446.93	428.85	431.20	430.02
	10	387.73	418.58	403.14	372.38	442.30	407.34	431.13	451.23	441.18	401.10	436.63	418.86
	Avg.	467.38	507.03	487.21	442.58	500.40	471.49	496.12	524.13	510.12	483.83	505.37	494.60
Leaf	1	600.08	651.83	625.95	584.10	631.50	607.80	619.45	649.53	634.49	586.68	664.65	625.66
	2	545.53	609.28	577.40	518.05	584.13	551.09	572.95	619.70	596.33	542.70	631.70	587.20
	3	541.25	598.00	569.63	494.55	569.45	532.00	553.80	616.58	585.19	536.40	598.23	567.31
	4	507.03	582.53	544.78	469.50	556.80	513.15	541.13	605.00	573.06	525.13	577.45	551.29
	5	498.50	585.48	541.99	449.40	527.78	488.59	526.65	596.18	561.41	503.28	568.05	535.66
	6	481.03	553.45	517.24	412.58	503.75	458.16	502.95	573.23	538.09	463.75	556.50	510.13
	7	469.20	522.53	495.86	405.78	481.25	443.51	485.63	545.98	515.80	458.25	546.30	502.28
	8	443.98	513.10	478.54	374.13	461.70	417.91	470.38	544.08	507.23	461.05	539.58	500.31
	9	436.48	505.20	470.84	378.05	461.65	419.85	491.10	525.18	508.14	444.40	510.85	477.63
	10	433.10	491.10	462.10	364.65	453.10	408.88	456.78	522.78	489.78	435.10	510.00	472.55
	Avg.	405.62	507.03	528.43	445.08	523.11	484.09	522.08	579.82	550.95	495.67	570.33	533.00
Stem	1	588.58	644.78	616.68	588.70	595.83	592.26	587.18	658.43	622.80	608.50	636.48	622.49
	2	574.78	586.93	580.85	531.05	567.33	549.19	556.78	608.78	582.78	596.43	591.28	593.85
	3	559.98	558.60	559.29	489.03	539.13	514.08	574.75	559.00	566.88	555.40	541.98	548.69
	4	499.68	493.73	496.70	466.88	524.48	495.68	542.38	524.95	533.66	533.23	480.70	506.96
	5	479.93	477.05	478.49	439.33	483.52	461.43	529.30	507.98	518.64	487.90	472.95	480.43
	6	443.93	450.13	447.03	408.13	476.30	442.21	482.85	469.75	476.30	458.63	437.90	448.26
	7	430.25	401.40	415.83	407.93	450.38	429.15	467.70	462.95	465.33	457.75	431.30	444.53
	8	385.95	393.83	389.89	369.88	437.15	403.51	453.85	448.33	451.09	423.90	434.48	429.19
	9	403.85	398.18	401.01	380.75	418.83	399.79	442.33	443.78	443.05	413.15	422.85	418.00
	10	382.20	383.53	382.86	379.73	414.70	397.21	414.50	442.35	428.43	395.05	416.25	405.65
	Avg.	474.91	478.81	476.86	446.14	490.76	468.45	505.16	512.63	508.89	492.99	486.61	489.80

Table A3. Mean neutral detergent fiber (NDF) of whole plant, leaf and stem samples of four old world bluestem cultivars as affected by date of harvest.

Plant Part	Harvest Date	Cultivar: Plains 1982	Plains 1983	Plains Avg.	Caucasian 1982	Caucasian 1983	Caucasian Avg.	Ganada 1982	Ganada 1983	Ganada Avg.	WW-Spar 1982	WW-Spar 1983	WW-Spar Avg.
		g Kg^{-1}											
Whole Plant	1	706.30	695.63	700.96	691.13	705.18	698.15	719.80	711.15	715.48	707.98	682.65	695.31
	2	720.95	712.60	716.78	715.55	706.50	711.03	732.35	725.03	728.69	634.15	697.10	665.63
	3	729.75	751.25	740.50	697.00	751.38	724.19	727.22	784.68	755.95	715.75	748.10	731.93
	4	734.05	764.13	749.09	727.50	751.88	739.69	754.30	801.58	777.94	714.30	784.55	749.43
	5	749.93	787.48	768.70	738.43	777.28	757.85	742.88	801.83	772.35	743.58	779.00	761.29
	6	755.88	790.90	773.39	726.45	784.43	755.44	756.73	825.25	790.99	747.30	796.43	771.86
	7	756.18	817.65	786.91	759.43	799.52	779.48	754.75	817.98	786.36	740.18	804.80	772.49
	8	765.78	808.18	786.98	775.60	809.97	792.66	744.00	825.85	784.93	746.08	795.00	770.54
	9	775.00	814.80	794.90	778.75	803.33	791.04	778.58	829.85	804.21	751.95	820.82	786.39
	10	776.60	826.83	801.71	776.13	792.90	784.51	774.93	825.63	800.28	777.13	811.25	794.19
	Avg.	747.04	776.94	761.99	738.60	768.21	753.40	748.55	794.88	771.72	727.83	771.97	749.90
Leaf	1	684.85	688.28	686.56	669.98	694.63	682.30	676.18	702.22	689.20	682.33	681.17	681.75
	2	710.18	707.95	709.06	691.30	687.30	689.30	703.85	691.58	697.71	698.15	665.83	681.99
	3	718.45	722.85	720.65	676.00	700.28	688.14	703.92	713.35	708.64	700.38	697.20	698.79
	4	706.08	716.78	711.43	675.57	682.83	679.20	709.30	694.80	702.05	685.53	672.68	679.10
	5	719.90	718.53	719.21	683.45	688.98	686.21	706.58	704.97	705.78	707.58	681.48	694.53
	6	719.38	714.80	717.09	681.90	669.80	675.85	715.23	701.85	708.54	710.00	675.48	692.74
	7	716.18	727.55	721.86	673.85	694.58	684.21	699.88	702.20	701.04	721.30	696.78	709.04
	8	730.33	709.85	720.09	682.68	684.80	683.74	750.15	701.63	725.89	694.50	667.98	681.24
	9	722.55	727.45	725.00	692.83	693.05	692.94	708.33	716.38	712.35	707.75	704.83	706.29
	10	705.10	723.05	714.08	697.38	683.03	690.20	722.43	712.68	717.55	713.15	669.45	691.30
	Avg.	713.29	715.71	714.50	682.49	687.93	685.21	709.58	704.17	706.87	702.07	681.29	691.68
Stem	1	730.30	715.73	723.01	709.85	737.43	723.64	737.20	736.40	736.80	629.55	699.93	664.74
	2	739.73	737.85	738.79	738.65	749.28	743.96	761.45	765.38	763.41	650.35	738.38	694.36
	3	739.68	774.78	757.23	731.20	805.25	768.23	744.75	824.25	784.50	738.00	774.45	756.23
	4	762.55	813.45	788.00	771.68	815.32	793.50	770.60	833.48	802.04	739.50	821.73	780.61
	5	789.03	830.83	809.93	796.45	835.23	815.84	767.50	852.80	810.01	776.58	818.00	797.69
	6	794.70	835.65	815.18	813.68	838.90	826.29	800.85	849.85	825.35	795.73	844.78	820.15
	7	801.68	877.35	839.51	812.33	866.83	839.58	802.60	841.77	822.19	766.20	849.45	807.83
	8	814.28	864.78	839.53	828.20	850.65	839.43	793.30	862.70	828.00	807.73	841.13	824.43
	9	816.15	864.20	840.18	830.90	866.10	848.50	816.33	861.70	839.01	810.28	850.10	830.19
	10	822.95	853.18	838.06	826.07	855.53	840.80	823.10	862.38	842.74	825.48	836.43	830.95
	Avg.	781.10	816.78	798.94	785.90	822.05	803.98	781.77	829.07	805.42	753.94	807.59	780.73

Table A4. Mean acid detergent fiber (ADF) of whole plant, leaf, and stem samples of four old world bluestem cultivars as affected by date of harvest.

Plant Part	Harvest Date	Plains 1982	Plains 1983	Plains Avg.	Caucasian 1982	Caucasian 1983	Caucasian Avg.	Ganada 1982	Ganada 1983	Ganada Avg.	WW-Spar 1982	WW-Spar 1983	WW-Spar Avg.
		g Kg^{-1}											
Whole Plant	1	388.75	345.35	367.05	375.28	371.43	373.35	378.55	357.10	367.82	383.75	356.45	370.10
	2	405.03	377.43	391.22	405.05	398.38	401.71	403.85	377.88	390.86	463.20	379.35	421.27
	3	416.25	422.63	419.44	415.68	439.22	427.45	413.55	437.95	425.75	399.93	421.53	410.72
	4	423.95	440.18	433.06	449.60	444.35	446.97	422.55	441.58	432.06	418.15	455.18	436.66
	5	434.18	455.30	444.74	440.35	464.80	452.57	424.50	449.22	436.86	428.93	454.63	441.77
	6	444.05	470.80	457.42	440.53	472.90	456.71	450.75	470.13	460.44	444.33	471.75	458.04
	7	471.55	484.20	477.87	486.50	487.70	487.10	447.73	468.90	458.31	449.80	478.75	464.27
	8	459.58	490.40	474.99	484.85	490.32	487.59	431.48	470.87	451.17	448.25	467.65	457.95
	9	468.18	483.63	475.90	483.02	483.03	483.02	448.08	470.95	459.51	422.38	482.78	452.57
	10	474.38	493.40	483.89	476.77	485.20	480.99	451.35	477.73	464.54	455.05	483.60	469.32
	Avg.	438.79	446.33	442.56	445.76	453.73	449.75	427.24	442.23	434.73	431.37	445.16	438.27
Leaf	1	357.83	334.73	346.27	358.78	348.70	353.74	365.80	346.60	356.20	350.90	345.03	347.96
	2	399.13	356.10	377.61	396.70	360.08	378.49	384.08	345.40	364.74	380.38	341.25	360.81
	3	390.00	374.43	382.21	394.48	371.15	382.81	379.30	358.73	369.01	376.65	364.98	370.81
	4	405.28	384.28	394.77	394.28	379.38	386.82	405.65	361.33	383.49	388.30	368.98	378.64
	5	406.28	385.48	395.87	383.95	383.50	383.72	386.40	367.48	376.94	390.00	371.17	380.59
	6	411.95	402.00	406.97	390.30	399.45	394.87	416.43	388.30	402.36	393.23	386.18	389.70
	7	419.18	411.40	415.29	410.30	401.33	405.81	404.37	385.88	395.12	430.13	392.43	411.27
	8	409.53	407.50	408.51	401.93	403.18	402.55	437.98	393.65	415.81	387.13	377.00	382.06
	9	413.98	411.88	412.92	387.75	406.85	397.30	405.33	399.47	402.40	384.00	403.15	393.57
	10	413.30	422.45	417.87	407.23	411.60	409.41	397.18	404.58	400.87	391.25	394.53	392.89
	Avg.	402.64	389.02	395.83	392.57	386.54	389.55	378.25	375.14	386.69	387.19	374.47	380.83
Stem	1	423.10	383.25	403.17	418.90	403.50	411.20	417.90	389.65	403.77	482.45	377.10	429.77
	2	432.45	408.53	420.49	445.33	434.68	440.00	438.25	406.90	422.57	487.18	399.23	443.20
	3	454.68	439.50	447.09	469.85	471.05	470.45	450.80	464.40	457.60	440.22	444.65	442.44
	4	481.13	487.88	484.50	499.68	484.68	492.17	451.83	472.57	462.20	456.15	493.08	474.61
	5	488.38	501.18	494.77	508.63	508.68	508.65	462.28	483.15	472.71	479.03	496.10	487.56
	6	511.48	515.13	513.30	516.73	512.33	514.53	490.73	509.75	500.24	493.73	521.53	507.62
	7	527.28	547.75	537.51	537.57	528.93	533.25	491.55	492.75	492.15	480.43	517.15	498.79
	8	520.43	539.80	530.11	527.15	523.85	525.50	483.40	502.10	492.75	510.15	502.43	506.29
	9	512.45	534.45	523.45	529.18	529.65	529.41	486.88	492.58	489.72	497.78	512.65	505.21
	10	516.43	533.10	524.76	525.18	534.23	529.70	494.93	498.08	496.50	513.55	513.98	513.76
	Avg.	486.78	489.05	487.92	497.82	493.15	495.49	466.85	471.19	469.02	484.06	477.79	480.93

Table A5. Mean acid detergent lignin (ADL) of whole plant, leaf, and stem samples of four old world bluestem cultivars as affected by date of harvest.

		Cultivar											
	Harvest	Plains			Caucasian			Ganada			WW-Spar		
Plant Part	Date	1982	1983	Avg.	1982	1983	Avg.	1982	1983	Avg.	1982	1983	Avg.
Whole Plant	1	50.85	27.90	39.37	42.70	36.77	39.74	51.60	32.75	42.17	50.70	35.30	43.00
	2	47.77	41.55	44.66	44.50	44.05	44.27	50.02	40.00	45.01	43.72	39.67	41.70
	3	48.67	47.85	48.26	45.67	52.72	49.20	45.97	53.00	49.49	43.37	50.35	46.86
	4	52.47	53.12	52.80	57.47	55.32	56.40	49.20	56.25	52.73	50.52	58.10	54.31
	5	59.00	57.85	58.42	58.62	60.45	59.54	48.12	57.65	52.89	53.72	58.65	56.19
	6	62.37	61.72	62.05	57.75	62.45	60.10	56.37	63.05	59.71	58.90	63.85	61.37
	7	65.02	65.47	65.25	66.22	65.70	65.96	51.95	63.30	57.62	55.57	65.25	60.41
	8	65.45	68.72	66.84	71.85	68.52	70.19	50.50	65.55	58.02	57.02	64.80	60.91
	9	67.47	66.97	67.22	72.32	67.10	69.71	58.22	65.55	61.89	56.35	68.00	62.17
	10	70.15	70.20	70.17	72.07	66.75	69.41	56.25	66.97	61.61	70.45	68.35	69.40
	Avg.	58.92	56.09	57.51	58.92	57.98	58.45	51.82	56.41	54.11	54.03	57.23	55.63
Leaf	1	43.82	28.47	36.15	38.85	30.95	34.90	35.45	30.80	33.12	41.97	25.55	33.76
	2	46.30	33.60	33.95	42.12	37.95	40.04	36.95	33.55	35.25	39.70	31.77	35.74
	3	45.40	37.97	41.69	39.77	38.22	39.00	40.35	37.15	38.75	42.95	36.85	39.90
	4	48.95	41.92	45.44	41.97	42.22	42.10	44.65	38.70	41.67	43.65	41.30	42.47
	5	51.50	40.67	46.09	46.40	44.37	45.39	39.72	40.57	40.15	46.35	41.87	44.11
	6	50.90	45.57	48.24	49.07	47.85	48.46	49.67	44.20	46.94	46.15	43.87	45.01
	7	50.30	49.87	50.09	51.77	50.42	51.10	41.52	46.97	44.25	51.50	43.27	47.39
	8	55.17	51.57	53.37	50.27	52.20	51.24	52.75	47.35	50.05	49.57	45.30	47.44
	9	54.90	50.15	52.52	51.85	52.25	52.05	46.27	47.72	47.00	47.90	48.70	48.30
	10	54.12	52.32	53.22	49.85	53.70	51.77	44.90	49.20	47.05	52.75	50.45	51.60
	Avg.	50.14	43.21	46.68	46.19	45.01	45.60	43.22	41.62	42.42	46.25	40.89	43.57
Stem	1	48.97	39.90	44.44	44.70	43.97	44.34	49.87	41.60	45.74	47.52	42.17	44.85
	2	50.75	50.45	50.60	51.10	52.07	51.59	46.97	50.65	48.81	46.00	51.30	48.65
	3	51.02	57.42	54.22	54.67	61.45	58.06	44.62	61.85	53.23	48.85	60.85	54.85
	4	63.30	69.10	66.20	67.92	65.12	66.52	53.05	65.72	59.39	56.67	71.82	64.25
	5	71.72	72.00	71.86	76.57	70.90	93.74	53.85	68.10	60.97	62.75	71.35	67.05
	6	80.62	76.50	78.56	80.65	71.65	76.15	66.67	74.87	70.77	70.60	78.25	74.42
	7	83.87	82.80	83.34	87.07	75.42	81.25	65.60	71.50	68.55	71.82	77.27	74.55
	8	63.20	82.77	72.99	85.80	77.07	81.43	64.90	74.30	69.60	75.90	75.52	75.71
	9	79.10	80.60	79.85	89.32	78.65	83.99	68.00	73.15	70.57	75.10	77.25	76.17
	10	82.92	81.82	82.37	62.22	78.32	70.27	67.27	72.55	69.91	78.50	77.60	78.05
	Avg.	67.55	69.34	68.44	70.00	67.46	68.73	58.02	65.43	61.76	63.37	68.34	65.86

Table A6. Mean crude protein (CP) content of whole plant, leaf, and stem samples of old world bluestem grasses as affected by date of harvest.

Plant Part	Harvest Date	Year 1982	1983	Aug.
		g Kg^{-1}		
Whole Plant	1	142.44	133.52	137.98
	2	127.03	107.57	117.30
	3	100.02	82.27	91.14
	4	85.06	70.62	77.84
	5	66.39	63.27	64.83
	6	66.44	52.55	59.49
	7	48.19	44.41	46.30
	8	50.31	35.76	43.03
	9	43.54	35.29	39.41
	10	38.41	32.61	35.51
	Avg.	76.78	65.79	71.28
Leaf	1	165.62	148.00	156.81
	2	141.14	122.26	131.70
	3	118.23	111.27	114.75
	4	105.66	102.69	104.18
	5	89.04	96.32	92.68
	6	86.17	84.14	85.15
	7	71.29	77.24	74.26
	8	67.81	66.67	67.24
	9	65.81	60.39	63.10
	10	58.30	57.20	57.75
	Avg.	96.91	92.62	94.76
Stem	1	105.86	92.84	99.35
	2	89.58	65.35	77.46
	3	68.49	53.88	61.18
	4	58.24	41.76	50.03
	5	47.43	38.14	42.78
	6	42.37	31.31	36.84
	7	34.57	26.39	30.48
	8	32.04	21.27	26.65
	9	29.26	19.77	24.52
	10	25.36	20.55	22.95
	Avg.	53.32	41.13	47.22

APPENDIX B

Listings of analyse of variances, and orthogonal contrasts of cultivars DM yield and quality components by year and by plant part.

List of Tables

Table B13. Mean square (MS) from the analyses of variance for neutral detergent fiber (NDF) and acid detergent fiber (ADF) for stem samples of the Plains, Caucasian, Ganada and WW-Spar cultivars.

Table B14. Mean square (MS) from the analyses of variance for acid detergent lignin (ADL) and crude protein (CP) for whole plant samples of the Plains, Caucasian, Ganada and WW-Spar cultivars.

Table B15. Mean square (MS) from the analyses of variance for acid detergent lignin (ADL) and crude protein (CP) for leaf samples of the Plains, Caucasian, Ganada and WW-Spar cultivars.

Table B16. Mean square (MS) from the analyses of variance for acid detergent lignin (ADL) and crude protein (CP) for stem samples of the Plains,Caucasian, Ganada and WW-Spar cultivars.

Table B1. Mean squares from the overall analyses of variance for in vitro dry matter disappearance (IVDMD), neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), and crude protein (CP) contents of four old world bluestem cultivars.

Source	d.f.†	IVDMD	NDF	ADF	ADL	CP
		$g\ Kg^{-1}$ (MS x 10^{-2})				
Rep (R)	3	170.33	68.56	7.00	0.98	116.78
Cultivar (C)	3	979.71**	220.21**	118.09**	12.85**	106.70
Error a	9	41.74	14.77	9.30	0.84	36.10
Harvest Date (HD)	9	3816.51**	766.09**	882.80**	78.02**	906.80**
C x HD	27	12.30**	10.95	9.73	0.92**	1.83
Error b	108	4.50	7.44	7.33	0.34	1.26
Year (Y)	1	3723.93**	1543.59**	4.01	0.004	201.36*
Error c	3	11.50	27.43	67.65	3.61	6.99
C x Y	3	119.76**	5.27	0.009	4.44**	8.20
Error d	9	11.92	20.42	7.43	0.59	3.91
HD x Y	9	10.71*	29.79**	73.74**	4.39**	8.26**
C x HD x Y	27	11.72**	9.72	8.21	0.72	1.28
Error e	108	4.48	6.91	6.86	0.46	0.81
Plant part (PP)	2	1377.55**	7761.54**	7269.47**	375.39**	1808.18*
Error f	6	12.54	4.33	6.63	0.71	4.79
C x PP	6	59.90**	52.19**	23.78*	0.73	4.61*
Error g	18	7.31	2.95	6.49	0.64	1.36
HD x PP	18	36.32**	139.65**	40.50**	3.81**	9.20**
C x HD x PP	54	5.40**	6.49*	4.40	0.30	0.69
Error h	216	2.98	4.10	3.42	0.33	0.51
PP x Y	2	645.14**	544.64**	124.48**	9.41**	14.53**
Error i	6	3.66	9.12	9.23	0.80	0.30
C x PP x Y	6	23.43**	26.86**	9.08	1.61**	1.71*
Error j	18	4.88	3.90	5.23	0.39	0.62
HD x PP x Y	18	9.53**	16.33**	10.25	0.93**	1.33**
C x HD x PP x Y	54	4.13**	5.14	4.59	0.43	0.69
Error k	216	2.29	4.25	3.52	0.32	0.51

*, **indicates significance at the 0.05 and 0.01 probability levels. df = degrees of freedom.
Error a = R x C; Error b = R x HD + R x C x HD; Error C = R x Y; Error d = R x C x Y;
Error e = R x HD x Y + R x C x HD x Y; Error f = R x PP; Error g = R x C x PP;
Error h = R x HD x PP + R x C x HD x PP; Error i = R x PP x Y; Error j = R x C x PP x Y;
Error k = R x HD x PP x Y + R x C x HD x PP x Y.

Table B2. Analysis of variance for DM yield and quality components in whole plants, 1982.

Source	df	Mean Squares	F
DM Yield			
Rep	3	220.22	
Cultivar (C)	3	974.63	8.75**
Harvest Date (HD)	9	2541.31	75.83**
C x HD	27	58.97	1.76*
IVDMD			
Rep	3	29.96	
Cultivar (C)	3	214.36	13.48**
Harvest Date (HD)	9	547.49	145.86**
C x HD	27	7.52	2.00**
NDF			
Rep	3	27.73	
Cultivar (C)	3	36.21	6.29*
Harvest Date (HD)	9	107.55	12.92**
C x HD	27	10.89	1.31
ADF			
Rep	3	11.24	
Cultivar (C)	3	26.81	5.34*
Harvest Date (HD)	9	112.96	12.80**
C x HD	27	10.00	1.13

Table B2. (Continued)

Source	df	Mean Squares	F
ADL			
Rep	3	3.60	
Cultivar (C)	3	5.12	9.49**
Harvest Date (HD)	9	8.67	26.93**
C x HD	27	0.88	2.73**
CP			
Rep	3	24.47	
Cultivar (C)	3	25.19	2.42
Harvest Date (HD)	9	208.99	195.59**
C x HD	27	1.43	1.34

*P<.05.
**P<.01.

Table B3. Analysis of variance for DM yield and quality components in whole plants, 1983.

Source	df	Mean Squares	F
DM Yield			
Rep	3	244.71	
Cultivar (C)	3	450.21	16.53**
Harvest Date (HD)	9	2288.02	69.72**
C x HD	27	43.65	1.33
IVDMD			
Rep	3	5.77	
Cultivar (C)	3	42.61	4.47*
Harvest Date (HD)	9	703.01	264.75**
C x HD	27	4.29	1.62
NDF			
Rep	3	15.42	
Cultivar (C)	3	55.77	11.01**
Harvest Date (HD)	9	295.90	92.17**
C x HD	27	3.33	1.04
ADF			
Rep	3	20.55	
Cultivar (C)	3	9.58	3.82
Harvest Date (HD)	9	314.87	193.30**
C x HD	27	2.02	1.24

Table B3. (Continued)

Source	df	Mean Squares	F
ADL			
Rep	3	0.15	
Cultivar (C)	3	0.29	4.45*
Harvest Date (HD)	9	22.51	223.54**
C x HD	27	0.15	1.44
CP			
Rep	3	7.54	
Cultivar (C)	3	9.98	2.99
Harvest Date (HD)	9	181.34	286.47**
C x HD	27	0.73	1.15

*P<.05.
**P<.01.

Table B4. Analysis of variance for DM yield and quality components in leaves, 1982.

Source	df	Mean Squares	F
DM Yield			
Rep	3	27.64	
Cultivar (C)	3	149.87	10.03**
Harvest Date (HD)	9	9143.70	28.78**
C x HD	27	7.63	1.53
IVDMD			
Rep	3	76.34	
Cultivar (C)	3	414.70	26.96**
Harvest Date (HD)	9	510.30	179.96**
C x HD	27	6.14	2.17**
NDF			
Rep	3	12.95	
Cultivar (C)	3	75.41	27.37**
Harvest Date (HD)	9	16.02	6.44**
C x HD	27	4.50	1.81*
ADF			
Rep	3	4.06	
Cultivar (C)	3	18.09	2.59
Harvest Date (HD)	9	40.06	14.75**
C x HD	27	4.32	1.59

Table B4. (Continued)

Source	df	Mean Squares	F
ADL			
Rep	3	1.28	
Cultivar (C)	3	3.21	6.87*
Harvest Date (HD)	9	2.87	11.34**
C x HD	27	0.24	0.95
CP			
Rep	3	51.49	
Cultivar (C)	3	33.69	2.76
Harvest Date (HD)	9	201.75	201.94**
C x HD	27	1.24	0.22

*P<.05.
**P<.01.

Table B5. Analysis of variance for DM yield and quality components in leaves, 1983.

Source	df	Mean Squares	F
DM Yield			
Rep	3	7.09	
Cultivar (C)	3	145.44	28.65**
Harvest Date (HD)	9	28.72	8.54**
C x HD	27	3.34	0.99
IVDMD			
Rep	3	52.75	
Cultivar (C)	3	247.26	15.60**
Harvest Date (HD)	9	421.87	126.83**
C x HD	27	4.55	1.37
NDF			
Rep	3	8.35	
Cultivar (C)	3	97.38	26.61**
Harvest Date (HD)	9	10.55	6.98**
C x HD	27	2.68	1.77*
ADF			
Rep	3	0.13	
Cultivar (C)	3	22.90	18.45**
Harvest Date (HD)	9	80.93	137.15**
C x HD	27	1.39	2.37**

Table B5. (Continued)

Source	df	Mean Squares	F
ADL			
Rep	3	1.53	
Cultivar (C)	3	1.34	4.15*
Harvest Date (HD)	9	8.69	102.49**
C x HD	27	0.08	0.99
CP			
Rep	3	29.24	
Cultivar (C)	3	29.45	2.85
Harvest Date (HD)	9	136.60	241.82**
C x HD	27	0.84	1.48

*P<.05.
**P<.01.

Table B6. Analysis of variance for DM yield and quality components in stems, 1982.

Source	df	Mean Squares	F
DM Yield			
Rep	3	77.34	
Cultivar (C)	3	389.34	8.49**
Harvest Date (HD)	9	1385.75	99.27**
C x HD	27	26.50	1.90*
IVDMD			
Rep	3	39.96	
Cultivar (C)	3	263.23	20.94**
Harvest Date (HD)	9	805.29	164.30**
C x HD	27	10.36	2.11**
NDF			
Rep	3	36.40	
Cultivar (C)	3	85.82	5.28*
Harvest Date (HD)	9	292.14	22.19**
C x HD	27	17.46	1.33
ADF			
Rep	3	41.34	
Cultivar (C)	3	65.68	5.22*
Harvest Date (HD)	9	133.48	10.59**
C x HD	27	12.33	0.98

Table B6. (Continued)

Source	df	Mean Squares	F
ADL			
Rep	3	0.67	
Cultivar (C)	3	10.91	5.71*
Harvest Date (HD)	9	23.78	18.95**
C x HD	27	1.50	1.19
CP			
Rep	3	18.89	
Cultivar (C)	3	25.97	4.66*
Harvest Date (HD)	9	118.20	189.33**
C x HD	27	1.33	2.14**

*P<.05.
**P<.01.

Table B7. Analysis of variance for DM yield and quality components in stems, 1983.

Source	df	Mean Squares	F
DM Yield			
Rep	3	126.56	
Cultivar (C)	3	110.58	8.67**
Harvest Date (HD)	9	1578.68	90.00**
C x HD	27	24.73	1.41**
IVDMD			
Rep	3	9.85	
Cultivar (C)	3	83.97	9.53**
Harvest Date (HD)	9	930.95	455.54**
C x HD	27	10.21	50.0**
NDF			
Rep	3	22.04	
Cultivar (C)	3	32.99	2.14
Harvest Date (HD)	9	381.68	161.58**
C x HD	27	5.06	2.14**
ADF			
Rep	3	29.05	
Cultivar (C)	3	40.83	3.45
Harvest Date (HD)	9	375.74	220.13**
C x HD	27	5.84	3.42**

Table B7. (Continued)

Source	df	Mean Squares	F
ADL			
Rep	3	0.39	
Cultivar (C)	3	1.10	5.47*
Harvest Date (HD)	9	25.39	319.79**
C x HD	27	0.27	3.42**
CP			
Rep	3	5.31	
Cultivar (C)	3	3.27	1.53
Harvest Date (HD)	9	89.24	406.62**
C x HD	27	0.29	7.36

*P<.05.
**P<.01.

Table B8. Mean squares (MS) from the analyses of variance for dry matter (DM) yield and In vitro dry matter disappearance (IVDMD) for whole plant samples of the Plains, Caucasian, Ganada and WW-Spar cultivars.

Source	df†	Plains 1982	Plains 1983	Caucasian 1982	Caucasian 1983	Ganada 1982	Ganada 1983	WW-Spar 1982	WW-Spar 1983
				DM Yield - (MS x 10^{-4})					
Reps (R)	3	451.14	131.35	12.06	8.93	36.18	75.79	54.86	110.36
Harvest Dates (HD)	9	6828.68	4421.51	7548.08	7857.67	2445.94	3050.50	6843.64	5978.02
HD_L	1	5982.44**	4179.51**	7358.64**	7841.22**	2208.35**	3025.16**	6242.55**	5961.06**
HD_Q	1	781.44**	215.15**	168.39**	3.69	208.39**	4.71	575.77**	0.024
Dev. from Quadratic	7	64.30	26.84	15.05	12.76	89.52	20.63	25.32	16.93
Error a‡	27	50.47	24.84	13.93	5.02	19.03	27.14	50.62	29.13
Years (Y)	1	416.94		7.31		110.53		73.45	
Error b‡	3	164.55		14.10		37.88		13.09	
Y x HD	9	208.33		117.98		143.97		321.78	
Y x HD_L	1	80.61		3.83		32.07		1.62	
Y x HD_Q	1	88.38		110.97		75.23		291.62**	
Y x $HD_{Dev.}$	7	39.34		3.18		36.67		28.54	
Error c‡	27	33.23		33.82		24.99		28.60	
				IVDMD					
Reps (R)	3	4059	137	198	1309	304	995	3204	996
Harvest Dates (HD)	9	146084	208252	13767	117466	78567	157262	116152	156071
HD_L	1	140298**	197439**	153965**	111149**	77943**	150187**	114989**	146327**
HD_Q	1	5493**	10427**	9523**	6272**	293	6972**	662	9403**
Dev. from Quadratic	7	298	386	279	45	331	103	501	341
Error a	27	454	315	357	310	403	209	288	227
Years (Y)	1	31438		66857**		15686*		9279*	
Error b‡	3	1565		640		514		355	
Y x HD	9	3147		2078		8242		4120	
Y x HD_L	1	2434*		1740*		5871**		8537**	
Y x HD_Q	1	392		169		2202**		640	
Y x $HD_{Dev.}$	7	320		169		169		877	
Error c‡	27	516		313		206			

*, **Significant at the 0.05 and 0.01 probability levels, respectively.
†df = Degrees of freedom.
‡Error a = R X HD; Error b = R X Y; Error c = R X Y X HD.

Table B9. Mean squares (MS) from the analyses of variance for dry matter (DM) yield and In vitro dry matter disappearance (IVDMD) for leaf samples of the Plains, Caucasian, Ganada and WW-Spar cultivars.

Source	df†	Plains 1982	Plains 1983	Caucasian 1982	Caucasian 1983	Ganada 1982	Ganada 1983	WW-Spar 1982	WW-Spar 1983
					DM Yield - (MS x 10^{-4})				
Reps (R)	3	57.70	19.50	0.42	1.28	9	.44	5.16	1.10
Harvest Dates (HD)	9	574.88	244.65	245	132	135	15	403	59
HD_L	1	251.61**	164.78**	165**	126*	38**	14**	171**	54**
HD_Q	1	312.72**	74.89**	75**	0.26	94**	.46	227**	2
Dev. from Quadratic	7	10.55	4.99	5	5	3.63	.49	4	3
Error a‡	27	8.40	2.19	2	7	2.13	1.58	7	2
Years (Y)	1	425*		16*		106**		486**	
Error b‡	3	16		1.11		3.64		.87	
Y x HD	9	147		39		46		155	
Y x HD_L	1	33*		1.28		3		16	
Y x HD_Q	1	106**		33*		40**		1.34**	
Y x $HD_{Dev.}$	7	7		4		3		4	
Error c‡	27	5		6		2		4	
					IVDMD				
Reps (R)	3	4011	2147	619	255	318	983	7301	6646
Harvest Dates (HD)	9	104442	96609	182960	4814	89239	68084	89332	87745
HD_L	1	100779**	95818**	173667**	1282**	84759**	67794**	86358**	84227**
HD_Q	1	3321**	331	8912	3255**	3985**	32	2534*	3216**
Dev. from Quadratic	7	342	460*	381	277	495**	258	440	302
Error a‡	27	354	170	312	404	128	568	341	190
Years (Y)	1	86152**		121781**		66678**		111475**	
Error b‡	3	152		529		555		392	
Y x HD	9	1009		2526		2432		471	
Y x HD_L	1	31		1720*		473		6	
Y x HD_Q	1	777		697		1652**		20	
Y x $HD_{Dev.}$	7	200		108		306		444	
Error c‡	27	232		258		302		224	

*, **Significant at the 0.05 and 0.01 probability levels, respectively.
†df = Degrees of freedom.
‡Error a = R X HD; Erro b = R X Y; Error c = R X Y X HD.

Table B10. Mean squares (MS) from the analyses of variance for dry matter (DM) yield and In vitro dry matter disappearance (IVDMD) for stem samples of the Plains, Caucasian, and WW-Spar cultivars.

Source	df†	Plains 1982	Plains 1983	Caucasian 1982	Caucasian 1983	Ganada 1982	Ganada 1983	WW-Spar 1982	WW-Spar 1983
		DM Yield - (MS x 10^{-4})							
Reps (R)	3	167	43	9	11	10	59	28	51
Harvest Dates (HD)	9	3319	294	4343	5155	1422	2505	3078	3940
HD_L	1	3118**	2877**	4275**	5117**	1372**	2487**	3520*	3930**
HD_Q	1	177**	59*	59**	19	33	2	138*	3
Dev. from Quadratic	7	24	3	9	19	17	15	20	6
Error a‡	27	17	10	7	30	9	17	22	13
Years (Y)	1	14		18		369*		28	
Error b‡	3	69		15		22		12	
Y x HD	9	31		101		134		114	
Y x HD_L	1	2		19		22*		5	
Y x HD_Q	1	15		72		27		93*	
Y x $HD_{Dev.}$	7	13		10		24		16	
Error c‡	27	11		28		12		14	
		IVDMD							
Reps (R)	3	2085	246	644	1536	1260	1224	3778	623
Harvest Dates (HD)	9	215298	298869	187115	143639	127464	203101	208626	212724
HD_L	1	210598**	279305**	169245**	140866**	126475**	182221**	205468**	182642**
HD_Q	1	3729*	19080**	175**	2643**	298	20766**	2766*	29625**
Dev. from Quadratic	7	971	484	319	130	691	114	392	457
Error a‡	27	741	202	405	162	346	232	469	222
Years (Y)	1	305		39828*		1115		813	
Error b‡	3	680		205		246		725	
Y x HD	9	5811		4198		15973		7939	
Y x HD_L	1	2421*		650		2537**		336	
Y x HD_Q	1	2969**		3286**		13020**		7143**	
Y x $HD_{Dev.}$	7	420		261		415		460	
Error c‡	27	437		274		231		355	

*, **Significant at the 0.05 and 0.01 probability levels, respectively.
†df = Degrees of freedom.
‡Error a = R X HD; Error b = R X Y; Error c = R X Y X HD.

Table B11. Mean squares (MS) from the analyses of variance for neutral detergent fiber (NDF) and acid detergent fiber (ADF) for whole plant samples of the Plains, Caucasian, Ganada and WW-Spar cultivars.

Source	df	Plains 1982	Plains 1983	Caucasian 1982	Caucasian 1983	Ganada 1982	Ganada 1983	WW-Spar 1982	WW-Spar 1983
					NDF				
Reps (R)	3	132	1065	163	807	800	583	3404	607
Harvest Dates (HD)	9	19696	72345	34962	50779	10675	63747	40459	78194
HD	1	19351**	66645**	34382**	44180**	10232	50570**	34208**	66153**
HD	1	304	5571**	1	6246**	1	12688**	3402	11409**
Dev. from Quadratic	7	41	219	579	353	442	489	2849	632
Error a	27	98	206	318	359	309	401	2605	318
Years (Y)	1	17883**		17541**		42925**		38954*	
Error b	3	931		322		277		1734	
Y x HD	9	8874		3956		14251		7657	
Y x HD	1	7086**		307**		7654**		2610**	
Y x HD	1	1636**		3112**		6216**		3905*	
Y x HD	7	152		537		381		1142	
Error c	27	221		405		328		1517	
					ADF				
Reps (R)	3	426	609	223	1508	320	618	1660	72
Harvest Dates (HD)	9	31009	91977	48723	59091	18769	60508	9085	70445
HD	1	30105**	79580**	44501**	48979**	16203**	48710**	6074	57965**
HD	1	738	12256**	3583**	9982**	2268*	11315**	603	12099**
Dev. from Quadratic	7	166	141	639*	130	298	483*	2408	381*
Error a	27	190	155	257	200	391	160	2691	137
Years (Y)	1	1138		1270		4496		3803	
Error b	3	968		1028		818		1148	
Y x HD	9	9528		1235		6376		18719	
Y x HD	1	5896**		54**		4363**		13255**	
Y x HD	1	3489**		802**		1725**		3650*	
Y x HD	7	143		379		288		1814	
Error c	27	188		291		282		1407	

*, **Significant at the 0.05 and 0.01 probability levels, respectively.
†df = Degrees of freedom.
‡Error a = R X HD; Error b = R X Y; Error c = R X Y X HD.

Table B12. Mean squares (MS) from the analyses of variance for neutral detergent fiber (NDF) and acid detergent fiber (ADF) for leaf samples of the Plains, Caucasian, Ganada and WW-Spar cultivars.

Source	df	Plains 1982	Plains 1983	Caucasian 1982	Caucasian 1983	Ganada 1982	Ganada 1983	WW-Spar 1982	WW-Spar 1983
					NDF				
Reps (R)	3	192	896	340	422	46	46	1544	569
Harvest Dates (HD)	9	4007	3148	1535	2393	6907	1002	2916	1140
HD	1	1554**	2068**	977**	1901	5265**	631	2189*	93
HD	1	2168**	778	328*	167	708	157	309	96
Dev. from Quadratic	7	285	302	230**	325*	934*	214	418	951**
Error a	27	143	188	59	123	292	142	501	151
Years (Y)	1	116		590		587**		8636	
Error b	3	520		386		6		1426	
Y x HD	9	453		1393		2632		1188	
Y x HD	1	18**		1016		1126**		690*	
Y x HD	1	174**		13*		766		30	
Y x HD	7	261		364		740		468*	
Error c	27	164		76		227		348	
					ADF				
Reps (R)	3	1346	106	307	75	495	136	354	68
Harvest Dates (HD)	9	9672	27094	9367	16318	10399	16680	8870	13503
HD	1	6786**	25247**	2622**	15589**	6831**	16576**	3933**	12717**
HD	1	2598**	1743**	6130**	701**	2764**	12	4155**	508**
Dev. from Quadratic	7	288	104	615**	28	804*	92	782	278**
Error a	27	166	95	92	33	258	66	570	43
Years (Y)	1	3710		727*		10681*		3240*	
Error b	3	880		60		561		222	
Y x HD	9	3087		3007		2642		2616	
Y x HD	1	2927**		2712**		1062**		1253**	
Y x HD	1	42**		2**		1202**		879**	
Y x HD	7	118		293**		378**		484	
Error c	27	106		59		202		337	

*, **Significant at the 0.05 and 0.01 probability levels, respectively.
†df = Degrees of freedom.
‡Error a = R X HD; Error b = R X Y; Error c = R X Y X HD.

Table B13. Mean squares (MS) from the analyses of variance for neutral detergent fiber (NDF) and acid detergent fiber (ADF) for stem samples of the Plains, Caucasian, Ganada and WW-Spar cultivars.

Source	df	Plains 1982	Plains 1983	Caucasian 1982	Caucasian 1983	Ganada 1982	Ganada 1983	WW-Spar 1982	WW-Spar 1983
					NDF				
Reps (R)	3	297	1793	303	872	628	1553	7287	2606
Harvest Dates (HD)	9	43064	110802	66736	73948	28836	67174	151010	97136
HD	1	42155**	92872**	61514**	62231**	28349**	49569**	134465**	72942**
HD	1	684*	17519**	4782**	11291**	6	13868**	14875	23914**
Dev. from Quadratic	7	225	411	440	426	481	737*	1670	280
Error a	27	159	228	205	179	215	290	4685	247
Years (Y)	1	25454		26136**		44751**		57411	
Error b	3	394		468		1190		6000	
Y x HD	9	10852		893		9123		6181	
Y x HD	1	4943**		15**		1473**		4668**	
Y x HD	1	5639**		688**		6656**		534**	
Y x HD	7	270		190		994		979	
Error c	27	160		186		305		2253	
					ADF				
Reps (R)	3	869	135	390	4571	25	1573	6426	1775
Harvest Dates (HD)	9	50350	121900	57061	70704	24017	57258	11381	94529
HD	1	43308**	103719**	46172**	60914**	21902**	41538**	7589	70540**
HD	1	6773**	17842**	10789**	9663**	1881*	15223**	2633	23363**
Dev. from Quadratic	7	263	339*	100	127	234	497	1159	626**
Error a	27	172	132	138	113	223	252	4508	185
Years (Y)	1	104		435		377		788	
Error b	3	367		3433		889		3546	
Y x HD	9	7868		607		5048		37950	
Y x HD	1	6492**		510**		1556**		15927**	
Y x HD	1	1315**		16**		3201**		20842	
Y x HD	7	61**		81		291		1181	
Error c	27	144		67		253		2223	

*, **Significant at the 0.05 and 0.01 probability levels, respectively.
†df = Degrees of freedom.
‡Error a = R X HD; Error b = R X Y; Error c = R X Y X HD.

Table B14. Mean squares (MS) from the analyses of variance for acid detergent lignin(ADL) and crude protein (CP) for whole plant samples of the Plains, Caucasian, Ganada and WW-Spar cultivars.

Source	df†	Plains 1982	Plains 1983	Caucasian 1982	Caucasian 1983	Ganada 1982	Ganada 1983	WW-Spar 1982	WW-Spar 1983
					ADL				
Reps (R)	3	310	3	31	3	44	13	137	17
Harvest Dates (HD)	9	2338	6610	4661	4113	333	4731	1710	4879
HD_L	1	2309**	5964**	4591**	3577**	232**	4024**	1525**	4286**
HD_Q	1	1	634**	31	531**	63	687**	101	577**
Dev. from Quadratic	7	28	12	39	5	38	20	84	16
Error a‡	27	39	9	23	14	22	8	46	9
Years (Y)	1	161		17		420		204	
Error b‡	3	166		12		35		117	
Y x HD	9	795		207		1782		969	
Y x HD_L	1	426**		31		1161**		349**	
Y x HD_Q	1	336**		153*		583**		581**	
Y x $HD_{Dev.}$	7	33		23		38		39	
Error c‡	27	28		22		16		16	
					CP				
Reps (R)	3	2591	633	25	13	333	75	2615	1036
Harvest Dates (HD)	9	38448	43825	54913	36404	46746	46319	44407	36112
HD_L	1	38256**	40972**	48093**	32160**	42724**	40859**	42550**	32645**
HD_Q	1	31**	2745**	6703**	4170**	3884**	5319**	1557**	3372**
Dev. from Quadratic	7	161	108*	117	74	138	141*	300	95
Error a‡	27	72	37	63	89	124	50	169	76
Years (Y)	1	1985		1041**		2308		5165*	
Error b‡	3	400		7		279		118	
Y x HD	9	136		1022		210		703	
Y x HD_L	1	23		799**		10		328	
Y x HD_Q	1	8		150		56		173	
Y x $HD_{Dev.}$	7	105		73		153		202	
Error c‡	27	58		53		89		131	

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

†df = Degrees of freedom.

‡Error a = R X HD; Error b = R X Y; Error c = R X Y X HD.

Table B15. Mean squares (MS) from the analyses of variance for acid detergent lignin (ADL) and crude protein (CP) for leaf samples of the Plains, Caucasian, Ganada and WW-Spar cultivars.

Source	df†	Plains 1982	Plains 1983	Caucasian 1982	Caucasian 1983	Ganada 1982	Ganada 1983	WW-Spar 1982	WW-Spar 1983
					ADL				
Reps (R)	3	41	50	52	41	27	13	148	144
Harvest Dates (HD)	9	529	2323	819	2045	720	1484	556	2001
HD_L	1	511**	2212**	768**	1967**	549**	1437**	539**	1870**
HD_Q	1	10	101**	33	73**	111	44	1	116**
Dev. from Quadratic	7	8	10	18	5	60	3	16	15
Error a‡	27	13	8	13	6	35	13	39	6
Years (Y)	1	958		28		51		573	
Error b‡	3	90		69		26		44	
Y x HD	9	336		150		144		274	
Y x HD_L	1	299**		138**		105		201**	
Y x HD_Q	1	24		4		8		50	
Y x $HD_{Dev.}$	7	13		8		31		23	
Error c‡	27	13		13		28		24	
					CP				
Reps (R)	3	3362	2053	82	94	575	340	4788	3238
Harvest Dates (HD)	9	38251	27717	43799	35060	55831	34675	44112	25371
HD_L	1	36582**	27243*	38989**	32861**	51645**	34385**	39744**	24348**
HD_Q	1	1514**	270*	4705**	2157**	4048**	269**	4279**	896**
Dev. from Quadratic	7	155	204	105	42	138	21	89	127
Error a‡	27	8	63	70	49	103	57	149	57
Years (Y)	1	1253		331		16		734	
Error b‡	3	214		33		275		211	
Y x HD	9	722		412		2076		1712	
Y x HD_L	1	343*		131		874**		938**	
Y x HD_Q	1	253		245*		1114**		629*	
Y x $HD_{Dev.}$	7	126		36		88		145	
Error c†	27	47		34		78		92	

*, **Significant at the 0.05 and 0.01 probability levels, respectively.
†df = Degrees of freedom.
‡Error a = R X HD; Error b = R X Y; Error c = R X Y X HD.

Table B16. Mean square (MS) from the analyses of variance for acid detergent lignin (ADL) and crude protein (CP) for stem samples of the Plains, Caucasian, Ganada and WW-Spar cultivars.

Source	df†	Plains 1982	Plains 1983	Caucasian 1982	Caucasian 1983	Ganada 1982	Ganada 1983	WW-Spar 1982	WW-Spar 1983
		ADL							
Reps (R)	3	128	6	180	24	88	60	244	10
Harvest Dates (HD)	9	5540	8207	8169	4995	2604	4386	5563	5636
HD_L	1	4895**	7015**	5003**	4436**	2516**	3308**	5458**	4321**
HD_Q	1	394	1181**	2949**	553**	6	1062**	62	1290**
Dev. from Quadratic	7	251	11	217	6	82*	16	43	25
Error a‡	27	249	7	194	6	16	10	43	8
Years (Y)	1	64		129		1080		493	
Error b‡	3	62		109		51		152	
Y x HD	9	228		610		538		471	
Y x HD_L	1	95		9		27		33	
Y x HD_Q	1	10		473*		451**		399**	
Y x $HD_{Dev.}$	7	123		128		60**		39	
Error c‡	27	128		104		13		20	
		CP							
Reps (R)	3	1217	469	61	87	162	37	2119	581
Harvest Dates (HD)	9	23556	20881	30150	21826	21544	19515	32148	16955
HD_L	1	21937**	18827**	24984**	18849**	19358**	16472**	30080**	14227**
HD_Q	1	1540**	1989**	5106**	2900**	2114**	2946**	1850**	2644**
Dev. from Quadratic	7	79	65	60	77**	72	97	218	84*
Error a‡	27	58	28	39	19	32	16	121	25
Years (Y)	1	3418*		1032*		1614*		7630*	
Error b‡	3	178		39		128		352	
Y x HD	9	124		394		149		1709	
Y x HD_L	1	59		216*		58		1467**	
Y x HD_Q	1	14		155*		34		35	
Y x $HD_{Dev.}$	7	51		23		57		207	
Error c‡	27	35		28		29		59	

*, **Significant at the 0.05 and 0.01 probability levels, respectively.
†df = Degrees of freedom.
‡Error a = R X HD; Error b = R X Y; Error c = R X Y X HD.

2

VITA

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Doctor of Philosophy

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