FORAGE YIELD AND QUALITY OF SEVERAL STRAINS AND STRAIN MIXTURES OF BERMUDAGRASS

By

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BERMUDAGRASS

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

With over three million acres of bermudagrass, <u>Cynodon dactylon</u> (L.), Pers., being utilized by grazing animals in Oklahoma, considerable concern has been raised by farmers, ranchers, and researchers with regard to the low animal gains in late summer and early fall months as reported by Elder and Murphy (1961). Improvement of quality and quantity of forage obtained by the grazing animal during this time of the year would mean a tremendous economic gain in livestock production.

Bermudagrass varieties and strains, most of which are vegetatively propagated clones, differ in their seasonal growth patterns. Harlan et al. (1954) noted that Midland bermudagrass begins growth earlier than Coastal in the spring, but the fall growth of Coastal is greater. Forage quality in bermudagrass also differs among strains. Burton (1972) showed Coastcross -1 bermudagrass to be approximately 12 per cent more digestible than Coastal when both forages were of comparable age and treatment. Factors which influence or relate to forage quality in terms of animal weight gains are the nutritive value of the forage and the rate of intake (Mott, 1973). Nutritive value is influenced by the chemical composition and digestibility, while the rate of intake by an animal is influenced by the acceptability of the forage and the rate of passage of that forage through the animal.

Forage research over the past few years has been pointed toward improving forage quality, however, almost no research has been done using vegetatively propagated species that differ in their seasonal growth patterns as mechanical mixtures. The objectives of this study were to (1) determine if vegetatively propagated bermudagrass clones differing in seasonal growth characteristics and other traits will establish as mixtures and to estimate the initial stability of these mixtures, (2) determine if these mechanical mixtures are more or less stable than their components with respect to seasonal production of forage and forage quality.

CHAPTER II

LITERATURE REVIEW

Early research and testing of bermudagrass produced such vigorous strains as Coastal (Burton, 1954), Midland (Harlan et al., 1954), and Greenfield (Elder, 1955). Coastal, which resulted from a natural cross between Tift bermudagrass and an introduction from South Africa, was very superior to the common types (Denman et al., 1971). Animal grazing studies in Georgia also indicated that approximately 680 pounds of beef per acre per year could be obtained from Coastal pastures fertilized annually with 200 pounds of nitrogen per acre. Midland bermudagrass, a hybrid between Coastal and a winterhardy common type from Indiana, showed good promise in regions north of the Coastal growing area because of its greater winterhardiness. Elder (1955) found Greenfield bermudagrass, another winterhardy type, to be far superior to the common types.

Studies were conducted at several locations in Oklahoma from 1962-1970 by Denman et al. (1971) comparing forage yields of Coastal, Midland, Greenfield, and Common. A mean difference of approximately 2,250 pounds of oven dry forage was found between the top and lowest yielding varieties. Coastal and Midland, the top yielding varieties, showed a difference of only nine pounds of forage per acre per year. Coastal has been shown to be three weeks later than Midland in initiating spring growth at several locations in Oklahoma. However, Coastal does make excellent growth from mid-summer into the fall months. These varieties were also well adapted to the deep sandy soils and under such conditions yielded 55 to 80 percent better than the other types from year to year.

It should be noted that forage production can be increased with applications of nitrogen fertilizer or by the use of legumes. Holt et al. (1951) stated that a lack of nitrogen was most often the factor limiting growth. Holt and Lancaster (1968) showed that increased fertilization with 240 pounds of nitrogen per acre per year on Coastal bermudagrass yielded approximately four tons of forage. Other studies by Chessmore (1964), Burton et al. (1956), and Decker (1959) showed a curvilinear increase in forage yields when fertilization increased from 300 to 1,500 pounds of nitrogen per acre per year. Harlan (1954) conducted a two pasture animal grazing test using bermudagrass and bermudagrass plus legumes. Bermudagrass fertilized with 100 pounds of nitrogen per acre per year yielded 180 pounds of beef per acre, while bermudagrass plus legumes yielded 250-300 pounds of beef per acre.

In general, increased nitrogen fertilization has increased not only total yield of bermudagrass but the nutritive value of the forage as well. Burton and DeVane (1952) reported an increase in crude protein percent of Coastal from seven percent in unfertilized hay to 13 percent when fertilized with 400 pounds of nitrogen per acre per year. Chessmore (1964), utilizing nitrogen increments up to 600 pounds per acre per year, reported crude protein of Coastal bermudagrass to increase from 8 to 12.5 percent.

With most forages, increasing age appreciably lowers nutritive value, voluntary intake, and consequently animal performance. Miller

(1964) evaluated the influence of harvesting age and season on the digestibility of pelleted Coastal bermudagrass. He found that digestibility of all components (organic matter, dry matter, protein, crude fiber) decreased as the age of the grass at harvest increased. Protein content declined substantially, but there was only a moderate increase in crude fiber. There was a tendency for the crude fiber levels to be highest in mid-season. Burton et al. (1956) evaluated the effects of nitrogen level and age on Coastal bermudagrass and found an increase in the percentage of forage consumed as the nitrogen rate increased. When rainfall was responsible for appreciable differences in the yield of two week and four week old grass, the cows showed a statistically significant preference for the younger forage. The protein content, moisture content, and yield increased with increasing increments of nitrogen up to 1,500, 200 to 300, and 600 to 900 pounds of nitrogen per acre, respectively. Prine and Burton (1956) showed the dry matter forage yield of Coastal to be reduced by approximately 50 percent when cut at two week rather than eight week intervals. However, reducing the harvest interval from eight to four weeks reduced forage yields by only 1,000 pounds.

Doss et al. (1966), Hallock et al. (1965) and Hart et al. (1965) have demonstrated that dry matter yields and crude protein content of bermudagrass can be increased by increasing the level of nitrogen fertilizer. The beneficial effect of nitrogen fertilization on digestibility has not been demonstrated as frequently. Meridith (1963) reviewed 22 papers reporting the effects of nitrogen fertilization on digestibility of several forage species and concluded that less than a one percent increase in digestibility was due, on the average, to higher nitrogen rates. Chapman (1972) evaluated samples of Pensacola bahiagrass (Bahia oppositifolia (Nutt.) DC.), Coastcross -1 bermudagrass, and Coastal bermudagrass in terms of steer performance. Both bahiagrass and Coastcross -1 bermudagrass were more digestible than Coastal. Coastcross -1 averaged 12 percent greater *in vitro* dry matter digestibility than Coastal.

Concern has been raised about the low daily gains made by animals grazing bermudagrass during the summer and fall months. Elder and Murphy (1961) reported that beef gains per acre were good during April, May, and June, but extremely low for the remainder of the growing season. McCroskey et al. (1968) conducted a study of the seasonal variation in the composition and digestibility of Midland bermudagrass. They found Midland to be of high quality for only the first 60 days of the growing season. Crude protein and cell contents were positively correlated with digestibility. High values for all three were obtained during the months of April, May, and June, but declined rapidly from April to July. Dry matter digestibility was negatively correlated with fiber and lignin portions of the plant. Forage intake increased as digestibility increased up to about 60 percent. Since digestibility is usually below 60 percent in later months, the cattle may not consume enough forage at times to promote rapid gains.

Numerous investigators have studied grass species in mixtures. Only limited work has been done on mixtures of grasses from the same species. Frankel (1939) wrote, "The blending of varieties in one crop, apart from its possible value as a yield stabilizer, may concievably raise the composite yield of the blend beyond the mean of its component yields when grown separately". Chapman (1969) studied the effects of planting rate and genotypic frequency on yield and seed size of two wheat (Triticum aestium L.) variety mixtures. When the mixtures were grown in row plantings, yields varied with the frequency proportions of the two varieties and showed significant positive deviations from predictions based on the weighted mean performance of components. The frequency was itself dependent on density. Seed size of mixtures showed no such frequency dependent effects although seed size increased significantly at lower population densities.

Clay (1969) studied the performance of homogeneous and heterogeneous barley (Hordeum vulgare L.) populations and mentioned several possible advantages of mixing different genetic types. These possible advantages are:

1. Greater yields through more efficient use of environment or positive genotypic interactions.
2. Greater yield stability over different environments.
3. Lower incidence of disease.

Research by Funk and Anderson (1964), Eberhart et al. (1964), Jensen (1965), and Ross (1965) indicated that mixtures generally have slightly higher yields than the mean of their components. However, the advantage was statistically significant in only 10 percent of the cases. Pfahler (1965), and Jensen (1965) suggest that yield stability, on the average, is more stable among mixtures than their components. Clay (1969) found in his research that mixture yields were not better than the mid-component.

Palvakul et al. (1973), working with blends of phenotypically similar and dissimilar winter barley, found that approximately 75 per cent of the blends they tried yielded better than the mid-component value. As a whole, the yield of the blends averaged two percent higher than the yields of the mid-components. Rai et al. (1971) tested the digestibility of mechanical mixtures of early and late cut tall fescue (*Festuca arundinacea*). They found that increasing the proportion of high quality forage in the mixture gave a linear increase in both *in vitro* and *in vivo* digestibility, however, this was not significant. Monson and Reid (1968) did research on the *in vitro* and *in vivo* digestibility and *ad libitum* intake of forage. Mixing forages of the same species or variety differing in *in vitro* dry matter digestibility had small and usually negative effects on the digestibility of the mixtures. The effects on *in vitro* dry matter digestibility tended to be greater when there were rather large differences in quality of the mixture components.

CHAPTER III

MATERIALS AND METHODS

Stillwater Bermudagrass Mixture Test

This research study was conducted on a Kirkland silt loam soil at the Agriculture Research Station at Stillwater, Oklahoma, during 1973 and 1974. The strains used in the test were Midland, Hardie, Oklan, Seed Set (SS)-16, and Selection (S)-15. With the exception of SS-16 these varieties have been tested in various locations across Oklahoma. Data in Table I demonstrates that they differ in their seasonal growth and quality characteristics. For instance, Hardie showed more early and late season growth while Midland was more productive than Hardie in mid-season. Coastal, which lacks winterhardiness, was more productive in latter portions of the growing season. Seasonal forage yields also vary depending on moisture and fertility conditions. Table II compares forage yields of Hardie and Midland at Goodwell in 1972 and 1973. Hardie was more productive than Midland and averaged 15 percent greater total seasonal dry matter production. However, Table I shows them to be approximately equal at the Mangum and Muskogee locations in 1970 and 1971. A brief description of the strains and seasonal growth characteristics of each will follow in the succeeding paragraphs.

Midland, a vegetatively propagated hybrid variety between Coastal bermudagrass and a winterhardy Indiana variety, was jointly released by the Georgia and Oklahoma Agriculture Experiment Stations. Midland is a

TABLE I

AVERAGE DRY MATTER YIELDS OF THREE BERMUDAGRASSES OVER TWO YEARS AT TO LOCATIONS*

Variety	Tons Dry Matter/Acre				
	Cut 1	Cut 2	Cut 3	Cut 4	Total
HARDIE	1.53	1.12	1.28	1.23	5.16
% of Total	29.7	21.7	24.8	23.8	
MIDLAND	1.13	1.46	1.43	1.15	5.17
% of Total	21.8	28.2	27.7	22.3	
COASTAL	0.60	1.09	1.25	1.02	3.96
% of Total	0.2	27.5	31.6	25.7	

* Yields were averaged from data obtained from tests conducted at Mangum and Muskogee during 1970 and 1971.

TABLE II

TONS OF DRY MATTER/ACRE OF TWO BERMUDAGRASSES AT GOODWELL IN 1972-73

Variety	1972*	1973*	72-73 Avg.	% of Midland
HARDIE	5.77	7.40	6.59	115.61
MIDLAND	4.93	6.47	5.70	-----

* Averaged over five cuts
** Averaged over four cuts

tall, leafy forage type with a lax open sod. It has good cold and drought resistance and starts spring growth two to three weeks earlier than Coastal. Midland yields have been shown, at several locations, to hold up well during times of stress. It has good digestibility until mid-season then quality declines in the summer and fall. Midland has small rhizomes that are long and straight, and seed head production is less than that of the common types. Midland requires high fertility for good results.

Hardie, a new release, is a vegetatively propagated hybrid that resulted from a three way cross made in 1967 by W. L. Richardson. It is an infertile hybrid that grows taller and has somewhat larger stems and broader, longer leaves than Midland. Hardie has large crooked rhizomes and is very winterhardy. These characteristics allow Hardie to establish and spread faster than Midland. Hardie characteristically produces more early season growth than Midland (Table I). With favorable conditions Hardie consistently gives better yields (Table II) and has averaged six percent better <u>in vitro</u> dry matter digestibility than Midland. High fertility is also needed for Hardie to give good results.

Oklan, a completely sterile vegetatively propagated hybrid, has a genetic background that is somewhat uncertain. It grows taller, has larger stems, broader and larger leaves than Midland and remains vegetative throughout most of the growing season. Oklan has only a small amount of rhizomes but spreads mainly by runners. Regrowth comes from buds and corm like rhizomes and density of sod is less than for Midland. Due to these characteristics, Oklan's region of adaptability is somewhat limited because it lacks winterhardiness and is not recommended for Northern Oklahoma. It generally begins growth seven to ten days later than Midland, however, yield surpasses Midland in middle and late season when favorable conditions exist. Oklan has averaged 9 to 10 percent higher in *in vitro* dry matter digestibility than Midland.

Due to an oversight in setting out this experiment, several of the plots, which contained Oklan, were contaminated with a strain of bermudagrass which is not being tested in this particular experiment. As a result, the contaminated as well as the remaining Oklan plots were deleted from the statistical analysis. However, by using the remaining Oklan and Oklan mixture plots an evaluation of their capabilities was made and the results are presented.

The two experimental hybrid strains used in the study were SS-16, and S-15. SS-16 is a very robust type which has characteristic long, thick runners and numerous rhizomes. Spreadability and coverage is very fast. This strain has leaves that are broader and shorter than Midland. SS-16 produces a large number of seed heads under certain conditions and will produce some viable seed. Seasonal production of SS-16 is similar to Oklan. This strain is a good producer of high quality forage in middle and late season if conditions are favorable. S-15, another experimental hybrid, is quite similar to Midland in height and leaf characteristics. This strain has good rhizome production and also produces a system of runners. However, compared to SS-16 it is slow to spread. S-15 is lower in seasonal production than Midland, but when good spring and fall moisture is available it is capable of better yields than Midland. Under hot and dry conditions S-15 does rather poorly.

The experimental design was a randomized complete block with four replications. Plots of grass were established by arranging eight plugs of grass, each measuring approximately three inches in diameter, lengthwise down the center of a 10 foot by 20 foot plot. There were 11 plots of grass per replication. Mixtures were achieved by arranging on an alternate plug basis. The plots of grass were sprigged on June 20, 1973 and the experimental area was irrigated after planting and whenever dry conditions existed.

Ammonium nitrate was applied at the rate of 220 pounds per acre (75 pounds of nitrogen) at the start of the experiment. Fertilizer at the same rate was again applied at the start of the 1974 growing season and after each subsequent harvest. Simazine, a selective herbicide, was applied at the beginning of the study. Application was in a spray form at the rate of two pounds active ingredient per acre.

Plots of grass were allowed to establish themselves the rest of the 1973 growing season and only growth observations were made. All plots of grass established rapidly and were completely covered by late summer, 1973. In the plots containing mixtures, visual ratings were made to indicate the percent contribution of each component grass to the total stand. The percent composition of each "mixture" plot was estimated prior to each harvest in 1974. Dates of harvest for 1974 are presented in Table III. Numerous investigators have shown digestibility of most forages to decrease as age at harvest increased. An effort was made to cut the bermudagrass forage at a good digestibility state (four weeks), however, climatic conditions prevented a consistent interval throughout the test. Plots of grass were harvested using an International Harvester cub tractor with a side mounted sickle mower with a tray attached for easy collecting of individual plot samples. Individual plots were sampled by collecting a 20 foot by 32 inch strip

TABLE III

HARVEST NUMBER AND HARVEST DATES INVOLVED IN THE EXPERIMENT

Harvest #	Harvest Date
1	May 30, 1974
2	July 10, 1974
3	August 14, 1974
4	October 3, 1974

from the center of the plot to eliminate border effect. This was weighed to obtain the pounds per plot weight. A smaller sample was then obtained from the plot weight portion to be used for chemical analysis. This smaller sample was weighed and then dried in an oven at approximately 165°F for one week. At this time dry weight samples were then ground and sent to the Forage Testing Laboratory at Ft. Reno near El Reno, Oklahoma. Each sample was chemically analyzed using the *in vitro* dry matter digestibility technique developed by Tilley and Terry (1963). Values obtained were percent crude protein, and percent *in vitro* dry matter digestibility.

The data were analyzed by harvesting date and yearly total on the computer using the Statistical Analysis System developed by Anthony James Barr and James Howard Goodnight of North Carolina State University. Analysis of variance was computed for pounds dry matter produced per acre, percent *in vitro* dry matter digestibility, percent crude protein, and seasonal averages.

Root Experiment

In the summer of 1973 a greenhouse experiment was conducted comparing dry root weights, dry top growth, and depth of root penetration of several bermudagrass strains. Midland, Hardie, Oklan, 69-A, and S-15 were grown in six foot long stovepipe cylinders filled with a washable type sand. Fertilizer was applied when needed in the liquid form of a commercially manufactured mix with a nitrogen-phosphorous-potassium analysis of 12-6-6. The experimental design was a four replicated randomized complete block. Plants were allowed approximately four months to develop root systems and were then removed and analyzed for dry root weights, top growth, and root depth.

CHAPTER IV

RESULTS AND DISCUSSION

Stillwater Bermudagrass Mixture Test

Composition of Mixture

Estimates of the percent plot composition of bermudagrass strains, grown in mechanical mixtures, were made prior to each harvest date in 1974 (Table IV). Strain SS-16, grown with Midland, maintained 55 percent of the mixture composition throughout the growing season. As the growing season progressed, strain SS-16, grown with Hardie, varied from 58 down to 55 percent of the mixture composition. Strain S-15 was unable to compete with the vigor of SS-16, therefore, strain SS-16 through the four harvests maintained 65 percent of the mixture composition. Further testing of those mechanical mixtures of bermudagrass is needed to adequately evaluate their long term compatability.

Forage Yields

Dry matter forage yields for each harvest date and for the seasonal total are presented in Table V. Forage yield means for harvest dates 5/30, and 10/3 are higher than they should be. If a more consistant harvesting interval had been maintained a more reasonable accessment of yield stability could have been made. Significant differences, at the .05 probability level, were found for the forage yield means at harvest

TABLE IV

ESTIMATES OF COMPONENT PERCENTAGES FOR MECHANICAL MIXTURES PRIOR TO EACH HARVEST DATE

Mixture	% SS-16/Harvest Date			
	5/30	7/10	8/14	10/3
Midland & SS-16*	55	55	55	55
Hardie & SS-16*	58	56	56	55
S-15 & SS-16*	65	65	65	65

Mixture	% Oklan/Harvest Date			
	5/30	7/10	8/14	10/3
Midland & Oklan**	40	38	38	38
S-15 & Oklan**	56	53	53	53

* Estimates are averaged over the four replications
** Estimates are averaged over three replications

TABLE V

DRY MATTERS YIELDS, 1974

Strain or Mixture	Lbs. DM/acre*				
	5/30**	7/10	8/14	10/3**	Seasonal Total**
Hardie	4340 a (30.5)	2540 (17.9)	2275 (16.0)	5057 a (35.6)	14,212 a
Hardie & SS-16	3910 a (28.5)	2194 (16.0)	2614 (19.1)	4991 a (36.4)	13,709 ab
Midland	4216 a (31.6)	2627 (19.7)	2294 (17.2)	4212 bc (31.5)	13,349 ab
Midland & SS-16	3919 a (30.6)	2381 (18.6)	2051 (16.0)	4438 ab (34.8)	12,789 b
SS-16	3970 a (31.5)	2281 (18.0)	1562 (12.3)	4835 ab (38.2)	12,648 b
S-15 & SS-16	2953 b (27.0)	1657 (15.1)	2611 (23.9)	3713 c (34.0)	10,934 bc
S-15	2934 b (29.3)	1560 (15.6)	1341 (13.4)	4169 bc (41.7)	10,004 c
CV. (%)	17.2	30.4	45.2	45.2	25.9

* % of total seasonal yield in parenthesis
**Significance at the .05 level was found for means on harvest dates 5/30, 10/3, and the seasonal total. No significance was found for means on harvest dates 7/10, and 8/14. All means followed by the same letter are not significantly different as computed by Duncan's Multiple Range Test at the .05 level.

dates 5/30, 10/3, and the seasonal forage yield totals. Using Duncan's Multiple Range Test, at the .05 probability level, forage yield means for harvest date 5/30 were separated into two groups. Strain S-15 and strain mixture S-15 and SS-16 had significantly lower dry matter yields than the other strains and strain mixtures. These yield differences are illustrated more clearly in Figure 1. No significant yield difference, at the .05 probability level, for the first harvest, was found between Hardie, Hardie and SS-16, Midland, Midland and SS-16, and SS-16 (Figure 1). Hardie produced 30.5 percent of its total seasonal forage yield at the 5/30 harvest date, compared to 31.6 percent for Midland (Table V). Previous evaluations (Table I) have shown Hardie to produce more forage per acre than Midland in early season harvests. The uncharacteristic response could be attributed to the late winter freeze which occurred on March 20, 1974 (Table VI). Hardie, a very winterhardy type which was already actively growing by March 20, was severely injured allowing the later emerging Midland to surpass it in forage yield. Strain SS-16 in the first harvest produced 31.5 percent of its total seasonal forage yield. Previous observations of this strain have not substantiated this response. One probable explanation can be linked also with the late winter freeze. Strain SS-16, being less winterhardy than Hardie or Midland, emerged later and was not affected by the freeze therefore, dry matter forage yield per acre was uncharacteristically good. Strain S-15, a good forage producer in spring and fall with favorable conditions, was low in forage production at the first harvest.

There is no apparent reason for this response because moisture and fertility were adequate during this period. Forage yield means for the May harvest of two strain mixtures, Hardie and SS-16 and Midland and

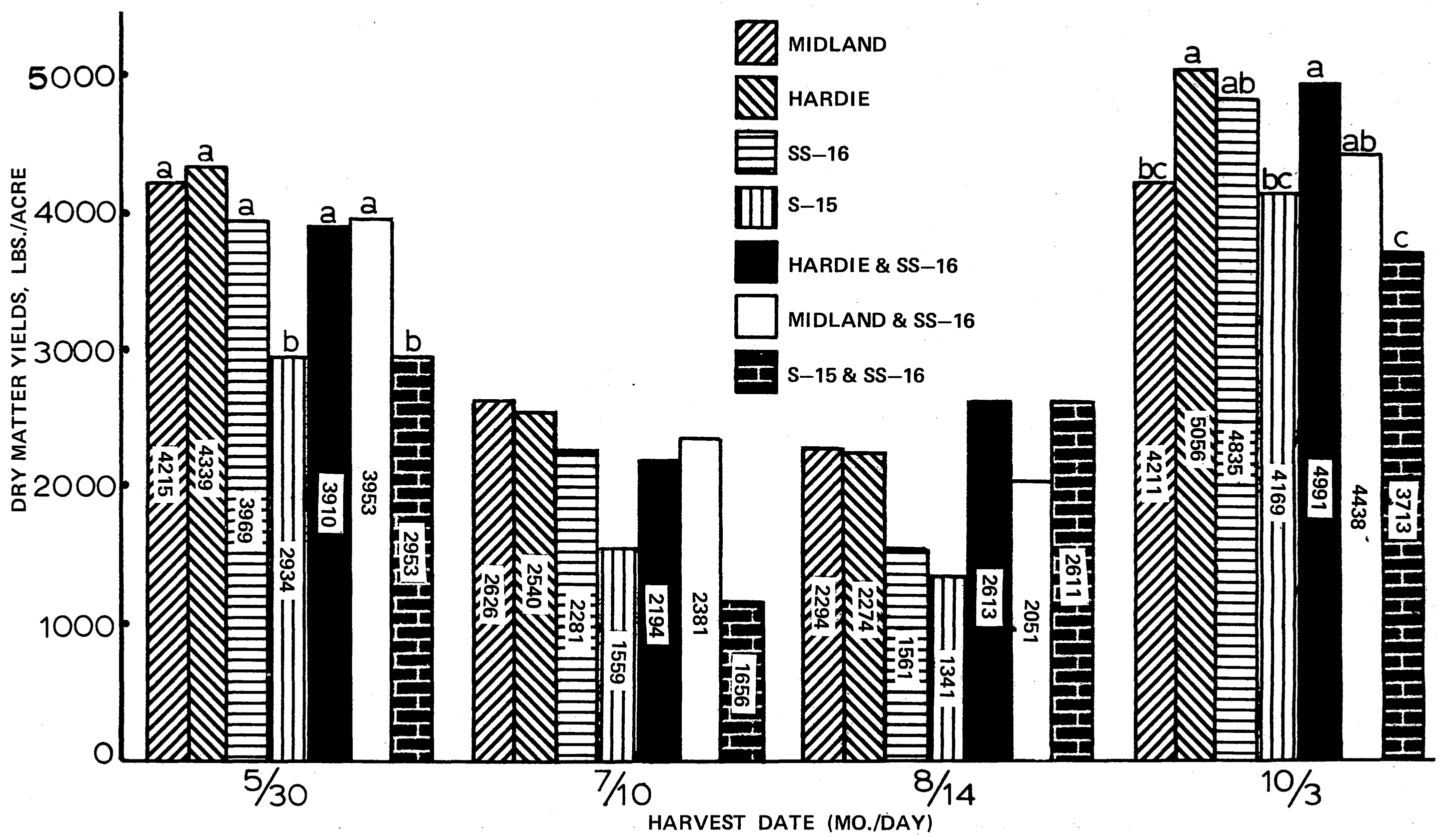

Figure 1. Average Dry Matter Yields by Harvest Date for 1974
Significance at the .05 level among strains and mixtures was found for harvest dates 5/30, and 10/3, but not for harvest dates 7/10, and 8/14. Strains or Mixtures with the same letter are not significantly different.

TABLE VI

TEMPERATURE AND PRECIPITATION DATA FOR THE STILLWATER STATION DURING 1973 AND 1974**

Month	Average Temperature (°F) 1973	1974	Departure from Norm 1973	1974
January	31.5	31.2	-6.4	-5.9
February	38.0	41.2	-4.2	-0.8
March	52.0	52.5*	2.4	3.7
April	55.2	59.6	-5.4	-1.5
May	66.2	71.2	-2.3	2.6
June	75.4	73.0	-2.5	-4.1
July	80.5	83.2	-2.0	1.4
August	78.9	77.5	-3.4	-3.8
September	7017	64.6	-3.5	-8.6
October	63.0	62.2	-0.5	-0.7
November	50.9	49.2	1.8	-0.3
December	37.7	38.4	-3.1	-1.7

Month	Total Precipitation (Inches) 1973	1974	Departure from Norm 1973	1974
January	3.24	0.51	2.08	-0.65
February	1.20	2.12	-0.15	0.77
March	7.73	3.16	5.87	1.30
April	3.44	2.48	0.58	-0.38
May	3.20	5.76	-1.42	1.14
June	2.15	2.39	-2.09	-2.23
July	4.35	0.63	0.82	-2.90
August	2.16	6.76	-1.05	3.55
September	12.41	6.03	9.03	2.65
October	2.44	7.87	-0.34	5.00
November	3.06	5.86	1.21	4.01
December	1.05	2.17	-0.29	0.83
Total	46.43	32.01	14.25	13.09

* Six days of below freezing temperatures occurred between March 20th and 27th.

** 1973 and 1974 norms are based on the periods between 1931-1960, and 1941-1970 respectively.

SS-16, were 3910 and 3919 pounds of dry matter per acre, respectively. These dry matter means were 28.5 and 30.6 percent of the total seasonal yields, respectively (Table V).

Dry matter yield means were not significantly different, at the .05 probability level, for harvest dates 7/10, and 8/14. Midland produced more dry matter per acre than Hardie in these two harvest. Data from Table VI shows precipitation during June and July of 1974, for the Stillwater station, to be below normal. The forage yield data substantiates previous observations that Midland will do better than Hardie during hot and dry times of the growing season. Forage yield means at harvest date 8/14 for two strain mixtures, Hardie and SS-16 and S-15 and SS-16, were greater than the forage yield means for the other strains or mixtures at that harvest date (Table V).

Forage yield means differed significantly, at the .05 probability level, for the October harvest. These yield means are segregated into three groups (Figure 1), however, the observable differences between groups do not exist like those at harvest date 5/30. October harvest data (Table V) show that Hardie produced 35.6 percent of its total seasonal forage yield, while Midland produced 31.5 percent of its total seasonal forage yield. Strains S-15 and SS-16 in the October harvest produced 38.2 and 41.7 percent of their total seasonal yields, respectfully. Mechanical mixtures, Hardie and SS-16 and Midland and SS-16, in the last harvest produced 4991 and 4438 pounds of dry forage per acre, respectively. Both these forage yield means were greater than Midland, however, only the mixture of Hardie and SS-16 was significantly greater at the .05 probability level.

Total seasonal dry matter yields were found significantly different at the .05 probability level. Seasonal forage yields for Hardie, Hardie and SS-16, and Midland were not significantly different with 14,212; 13,709; and 13,349 pounds of dry matter per acre, respectively. Seasonal forage yields of Midland, strain SS-16, and the mechanical mixtures showed no significant difference at the .05 probability level. Strain S-15, grown in monoculture, was significantly different from the other strains and mixtures with the exception of mixture S-15 and SS-16.

In Vitro Dry Matter Digestibility

The bermudagrass strains and strain mixtures did not differ significantly in *in vitro* dry matter digestibility (IVDMD), at the .05 probability level, at any harvest date and for the seasonal average. Digestibility values for the first and last harvest dates are lower than they should be due to the stage of maturity of the bermudagrasses at harvest time. Midland was the lowest in average IVDMD for the growing season (Table VII). Hardie was the best in digestibility with an average IVDMD of 61.49 percent. Digestibility of strain SS-16 averaged 61.29 percent and had greater digestibility than the other strains and strain mixtures for harvest date 7/10. Strain S-15 was the lowest in digestibility for the first two harvest dates, however, it maintained a 61 percent digestibility level the last two harvest dates. The results indicated that the digestibility of the mixtures seemed to stabilize at approximately 60 percent (Table VII). This stability is shown more clearly by Figure 2. Digestibility averages over the season for the varieties and strains grown in monoculture have a tendency to be more variable than those of the mechanical mixtures. With the exception of

TABLE VII

IN VITRO DRY MATTER DIGESTIBILITY, 1974

Strain or Mixture	% *In Vitro* Dry Matter Digestibility*				
	5/30	7/10	8/14	10/3	Seasonal Average
Hardie	58.34	61.38	66.36	59.87	61.49
SS-16	58.51	62.23	66.29	58.12	61.29
S-15 & SS-16	59.53	60.40	62.59	59.44	60.49
Midland & SS-16	58.40	59.57	67.33	56.66	60.49
Hardie & SS-16	58.74	61.02	61.99	58.43	60.04
S-15	56.14	57.89	61.78	61.74	59.31
Midland	57.74	59.64	61.06	55.70	58.54
CV. (%)	4.6	4.7	7.2	5.1	4.6

*IVDMD percentages were not significant at the .05 level

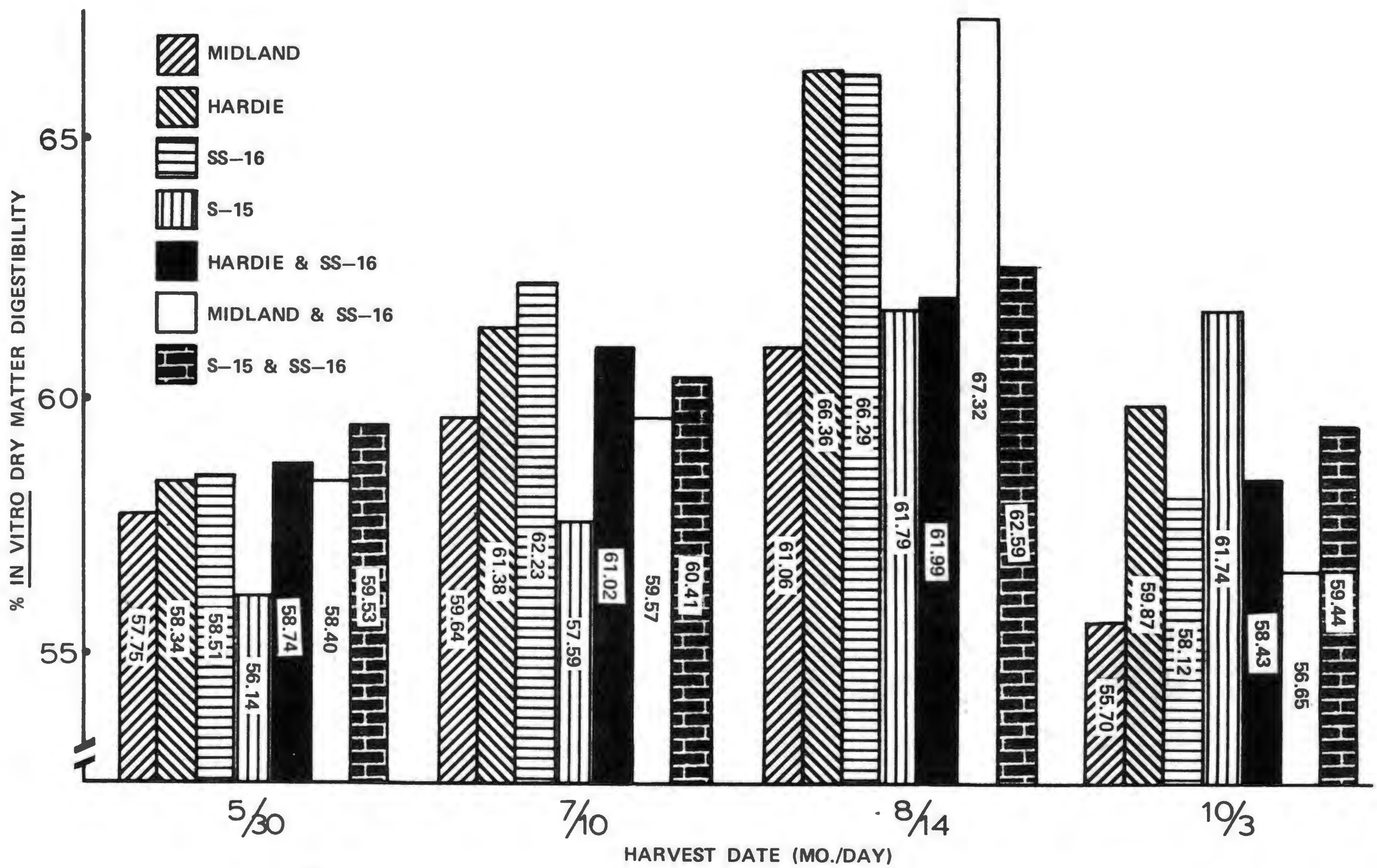

Figure 2. Average In Vitro Dry Matter Digestibility Percentages by Harvest Date for 1974. Significance among strains and mixtures was not found for any of the harvest dates.

Midland and SS-16 on harvest date 10/3, none of the three mixtures dropped below 58 percent IVDMD. Digestibility of Midland and SS-16 was greater than the other strains and strain mixtures in the August harvest with 67.32 percent IVDMD. Table VIII compares digestibility for each mechanical mixture with its components and a mid-component average. Digestibility averages of mechanical mixtures, Midland and SS-16 and S-15 and SS-16, proved to be greater than at least one of their components, and digestibility of both mixtures was greater than their respective mid-component IVDMD averages.

Crude Protein

The bermudagrass strains and strain mixtures did not differ significantly in crude protein, at the .05 probability level, for any of the harvest dates. Crude protein percentages for the first and last harvest dates are low due to the stage of maturity of the bermudagrass at harvest time. Table IX shows Midland to be the highest in crude protein with a seasonal average of 18.24 percent. Hardie and the mixture of Hardie and SS-16 proved to be the lowest in crude protein with 16.20 and 15.37 percent, respectively. Crude protein of strain SS-16 in the last three harvests was greater than 16 percent, and this strain had a seasonal average of 17.70 percent. Strain S-15 showed a crude protein average of 17 percent. Figure 3 shows that all crude protein levels for the bermudagrass strains and strain mixtures reached a peak at the third harvest and then rapidly declined. There was a tendency for most of the mixtures to stabilize crude protein over the span of the growing season. For instance, as the season progressed, crude protein for the mechanical mixture of S-15 and SS-16 fluctuated from 14.9 to 19.1 percent. Crude

TABLE VIII

COMPARISON OF COMPONENTS WITH MIXTURES FOR % CRUDE PROTEIN, % *IN VITRO* DRY MATTER DIGESTIBILITY, AND FORAGE YIELD/ACRE

Strain or Mixture	Average % Crude Protein	Average % IVDMD	Tons of Forage/Acre
Midland	18.24	58.54	6.67
SS-16	17.70	61.29	6.32
Midland & SS-16	17.00	60.49	6.39
*Midcomponent Average	17.97	59.91	6.49
Hardie	16.20	61.49	7.10
SS-16	17.70	61.29	6.32
Hardie & SS-16	15.37	60.04	6.85
*Midcomponent Average	16.95	61.39	6.71
S-15	17.00	59.31	4.73
SS-16	17.70	61.29	6.32
S-15 & SS-16	16.83	60.49	5.46
*Midcomponent Average	17.35	60.30	5.52

* Midcomponent average was computed by averaging values for the components within each mixture.

TABLE IX

CRUDE PROTEIN, 1974

Strain or Mixture	% Crude Protein*				
	5/30	7/10	8/14	10/3	Seasonal Average
Midland	17.24	18.39	21.44	15.91	18.24
SS-16	13.89	16.71	23.88	16.33	17.70
Midland & SS-16	15.67	16.42	20.62	15.32	17.00
S-15	14.92	18.11	20.12	14.88	17.00
S-15 & SS-16	14.93	17.90	19.09	15.43	16.83
Hardie	14.02	17.41	19.88	13.48	16.20
Hardie & SS-16	12.82	15.74	18.44	14.50	15.37
CV. (%)	15.2	7.3	14.8	10.4	14.1

* Crude protein percentages were not significant at the .05 level.

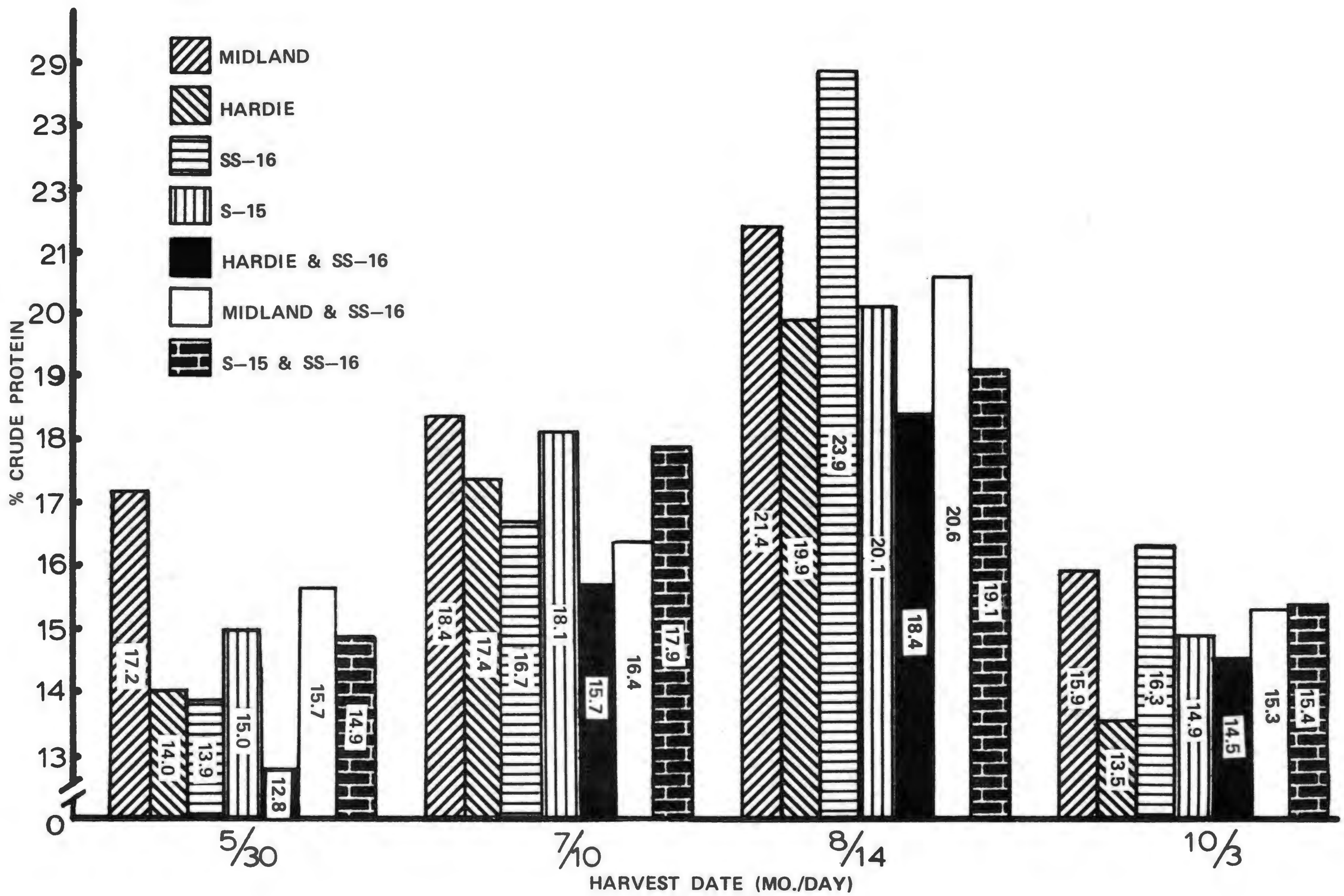

Figure 3. Average Crude Protein Percentages by Harvest Date for 1974 Significance among strains and mixtures was not found for any of the harvest dates.

protein for strain SS-16 fluctuated from 13.9 to 23.9 percent. Table VIII compares average crude protein percentages of each bermudagrass mixture with its components and a mid-component average. Average crude protein percentages for all mixtures were below their respective component averages and 1 to 1½ percent below their respective mid-component averages.

Oklan

Data on Oklan bermudagrass, grown in monoculture and as a mixture with Midland and S-15, are presented in Table X. Oklan digestibility throughout the season was greater than 61 percent IVDMD, and the seasonal IVDMD average was 62.49 percent. This digestibility average, is greater than those strains and strain mixtures in the IVDMD statistical analysis. Dry matter production of Oklan bermudagrass was lower than S-15 with 9,319 and 10,004 pounds of dry matter per acre, respectively (Tables V and X). The majority of Oklan's dry matter yield was produced in the latter two harvests of the growing season. Crude protein throughout the growing season averaged 18.06 percent. The mechanical mixture of Midland and Oklan produced 11,600 pounds of dry matter per acre, and 36 percent of this dry matter yield was at the last harvest date. Table IV shows the majority of this dry matter yield to be the Midland component. Digestibility of this mixture averaged below the Oklan IVDMD average. Crude protein for the strain mixture of Midland and Oklan was approximately 18 percent. The mechanical mixture of S-15 and Oklan showed a very low yield, however, digestibility of this mixture averaged 62.95 percent. Crude protein percent of the mixture, S-15 and Oklan, was greater than the crude protein percent for Oklan. This mixture was 53 to 56 percent Oklan throughout the growing season (Table V).

TABLE X

OKLAN DATA

Strain or Mixture	Lbs. Dry matter/acre*				
	5/30	7/10	8/14	10/3	Seasonal Total
Oklan**	2357 (25.3)	1998 (21.4)	2502 (26.8)	2462 (26.5)	9,319
Midland & Oklan***	2886 (24.7)	2087 (17.9)	2462 (21.1)	4222 (36.3)	11,657
S-15 & Oklan***	1871 (21.0)	1624 (18.2)	1702 (19.1)	3732 (41.7)	8,930
Strain or Mixture	**% *In Vitro* Dry Matter Digestibility**				
	5/30	7/10	8/14	10/3	Seasonal Average
Oklan**	61.78	62.81	63.26	61.97	62.46
Midland & Oklan***	59.82	62.78	63.33	59.86	61.45
S-15 & Oklan***	60.59	62.50	66.47	62.25	62.95
Strain or Mixture	**% Crude Protein**				
	5/30	7/10	8/14	10/3	Seasonal Average
Oklan**	17.99	19.03	20.28	14.95	18.06
Midland & Oklan***	17.48	20.01	19.67	15.01	18.04
S-15 & Oklan***	16.75	18.62	21.60	16.04	18.25

* % of total seasonal yield in parenthesis
** Averaged over two replications
*** Averaged over three replications

Root Experiment

The five bermudagrass strains, grown in six foot long cylinders, were significantly different, at the .05 probability level, for dry root weights, dry top growth, and depth of root penetration. A Duncan's Multiple Range Test on each of these variables was computed and the results appear in Table XI. Hardie produced more root and top growth than the other strains of bermudagrass, however, root and top growth values did not differ significantly, at the .05 probability level, from bermudagrass strains Oklan and 69-A. Midland was lower than Hardie and Oklan in grams of dry root weight, grams of dry top growth, and feet of root penetration (Table XI). Midland's root system, compared to root systems of Hardie and Oklan, was found to be very dense in the upper four feet of the root zone. This may facilitate the greater utilization of moisture in the upper levels of the soil profile. Root systems of Hardie and Oklan were distributed over a soil depth of six feet, while Midlands root system only penetrated a soil depth of four feet. Strain S-15 was rather low in grams of dry root weight, and grams of dry top growth, however, a root penetration depth of four feet was achieved. Strain S-15 has a very poor forage yield response during hot and dry stress periods, and the lack of a root system, comparable to Hardie or Midland, would be a probable cause for the poor response.

TABLE XI

COMPARISON OF DRY ROOT WEIGHTS, DRY TOP GROWTH, AND DEPTH OF ROOT PENETRATION, OF FIVE BERMUDAGRASS STRAINS GROWN IN SIX FOOT CYLINDERS*

Strains	Dry Root Wts. (Grams)	Dry Top Growth** (Grams)	Depth of Root Penetraion ** (Feet)
Hardie	31.9 a	120.0 a	6 a
Oklan	20.5 ab	96.5 ab	6 a
69-A	18.3 ab	97.3 ab	6 a
Midland	11.4 b	53.3 b	4 b
S-15	5.6 b	48.5 b	5 b
CV. (%)	0.63	0.37	0.096

* Values were computed using the average of four replications
**Significance at the .05 probability level was found for all three variables. A Duncan's Multiple Range Test was computed and strains followed by the same letter are not significantly different.

CHAPTER V

SUMMARY AND CONCLUSIONS

Stillwater Bermudagrass Mixture Test

The objectives of this study were to 1) determine if vegetatively propagated bermudagrass clones differing in seasonal growth characteristics and other traits will establish as mixtures and to estimate the initial stability of these mixtures 2) determine if these mixtures are more or less stable than their components with respect to seasonal production of forage and forage quality. The strains and mechanical mixtures used consisted of: "Midland", "Hardie", "Oklan", "SS-16", "S-15", "Midland and SS-16", "Hardie and SS-16", "S-15 and SS-16", "Midland and Oklan", and "S-15 and Oklan". Strain SS-16 was most competitive and usually constituted more than 50 percent of the mixture in which it occurred. In strain mixtures with Midland and S-15, Oklan's percent composition varied, being greater than 50 percent in mixture with S-15 and lower than 50 percent in mixture with Midland. Mixture composition may change due to its dependence on the vigor of the two strains, therefore; further evaluation is needed to determine what long term effect strains such as SS-16 have on the mixture composition.

Average dry matter yields of the strains in monoculture and in mixtures were statistically different ($P. < .05$) for two of the four harvest dates and for the seasonal total yields. No significance ($P. > .05$) among strains and strain mixtures was found for <u>in vitro</u>

dry matter digestibility or crude protein content throughout the season. Dry matter yield and quality responses for most mixtures seemed to be more linear than that for the component strains in monoculture.

More extensive evaluation of mechanical mixtures of two bermudagrass strains will be needed to truly access the role they can play in bermudagrass management.

Root Experiment

The objective of this greenhouse experiment was to compare dry root weights, dry top growth, and depth of root penetration of several bermudagrass strains. Strains used in the experiment were: "Hardie", "Midland", "Oklan", "S-15", and "69-A".

The five bermudagrass strains differed significantly ($P. < .05$) in dry root weight, dry top growth, and depth of root penetration. Hardie produced the greatest root and top growth and root penetration reached a depth of six feet, however, no significant difference ($P. > .05$) for the three variables was found between it, Oklan, and 69-A. Midland and S-15 had the lowest root and top growth dry weights. Midland's root system was very fibrous in the upper four feet of the soil profile, however; almost no roots penetrated deeper than this zone. In comparison, root systems of Hardie, Oklan, 69-A and S-15 were less fibrous within the upper four feet of the soil profile and penetrated soil depths greater than four feet.

LITERATURE CITED

1. Burton, G. W. 1954. Coastal bermudagrass. Ga. Agric. Exp. Sta. Bull. N-52.

2. Burton, G. W., and E. H. DeVane. 1952. Effect of rate and method of applying different sources of nitrogen upon the yield and chemical composition of bermudagrass, Cynodon dactylon (L.) Pers., hay. Agron. Jour. 44:128-132.

3. Burton, G. W., B. L. Southwell, and J. C. Johnson. 1956. The palatability of Coastal bermudagrass, Cynodon dactylon (L.) Pers., as influenced by nitrogen level and age. Agron. Jour. 48:360-362.

4. Chapman, H. D., W. H. Marchant, P. R. Utley, R. E. Hellwig, and W. G. Monson. 1972. Performance of steers on Pensacola bahiagrass, Coastal bermudagrass, and Coastcross -1 bermudagrass pastures and pellets. Jour. Ani. Sci. 38:373-378.

5. Chapman, S. R., R. W. Allard, and J. Adams. 1969. Effect of planting rate and genotypic frequency on yield and seed size in mixtures of two wheat varieties. Crop. Sci. 9:575-576.

6. Chessmore, R. A. 1964. Bermudagrass management. The Samuel Roberts Noble Foundation, Inc. Agric. Division Bull. 20 pages.

7. Clay, R. E., and R. W. Allard. 1969. A comparison of the performance of homogeneous and heterogeneous barley populations. Crop Sci. 9:407-412.

8. Decker, M. A. 1959. Midland bermudagrass: A new forage grass for Maryland. Maryland Agric. Exp. Sta. Bull. 465.

9. Denman, C. E., W. W. Huffine, and J. D. Arnold. 1971. Bermudagrass forage production in Oklahoma 1962-1970. Okla. Agric. Exp. Sta. Bull. B-692.

10. Doss, B. D., D. A. Ashley, O. L. Bennett, and R. M. Patterson. 1966. Interactions of soil moisture, nitrogen, clipping frequency on yield and nitrogen content of Coastal bermudagrass. Agron. Jour. 58:510-512.

11. Eberhart, S. A., L. H. Penny, and G. F. Sprague. 1964. Intraplot competition among maize single crosses. Crop Sci. 4:467-471.

12. Elder, W. C. 1955. Greenfield bermudagrass. Okla. Agric. Exp. Sta. Bull. B-455.

13. Elder, W. C., and H. F. Murphy. 1961. Grazing characteristics and clipping responses of bermudagrass. Okla. Agric. Exp. Sta. Bull. B-577.

14. Frankel, O. H. 1939. Analytical yield investigations on New Zealand wheat. IV. Blending varieties of wheat. Jour. Agric. Sci. 29:249-261.

15. Funk, C. R., and J. C. Anderson. 1964. Performance of mixtures of field corn (*Zea Mays* L.) hybrids. Crop Sci. 4:353-356.

16. Hallock, D. L., R. H. Brown, and R. E. Blaser. 1965. Relative yield and composition of Ky. 31 fescue and Coastal bermudagrass. Agron. Jour. 57:539-542.

17. Harlan, J. R., G. W. Burton, and W. C. Elder. 1954. Midland bermudagrass, a new variety for Oklahoma. Okla. Agric. Exp. Sta. Bull. 416.

18. Hart, R. H., G. W. Burton, and J. E. Jackson, 1965. Seasonal variation in chemical composition by nitrogen fertilization schedule. Agron. Jour. 57:381-382.

19. Holt, E. C., and J. A. Lancaster. 1968. Bermudagrass production and management in East Texas. Texas Agric. Exp. Sta. Bull. B-1073.

20. Holt, E. C., R. C. Potts, and J. F. Fudge. 1951. Bermudagrass research in Texas. Texas Agric. Exp. Sta. Circ. 129.

21. Jensen, N. F. 1965. Multiline superiority in cereals. Crop Sci. 5:566-568.

22. McCroskey, J. E., N. E. Brackett, and R. Renbarger. 1968. Seasonal variation in the composition and digestibility of Midland bermudagrass. Okla. Ani. Sci. Res. Prog. Report No. 80.

23. Meridith, W. R., Jr. 1963. Influence of nitrogen fertilization on forage quality. Report 20th South. Past. Forage Crops Improv. Conf. :46-51.

24. Miller, W. J., C. M. Clifton, O. L. Brooks, and E. R. Beaty. 1965. Influence of harvesting age and season on digestibility and chemical composition of pelleted Coastal bermudagrass. Jour. Dairy Sci. 48:209-212.

25. Monson, W. G. and J. T. Reid. 1968. *In Vitro* and *In Vivo* digestibility and *Ad libitum* intake of mechanical mixtures of forages. Agron. Jour. 60:610-612.

26. Mott, G. O. 1966. "Forages", Edited by Hughes, Metcalf and Heath. Iowa State Univ. Press. p. 108-118.

27. Palvakul, M., V. C. Finkner, and D. L. Davis. 1973. Blendability of phenotypically similar and dissimilar Winter Barley cultivars. Agron. Jour. 65:74-77.

28. Pfahler, P. L. 1965. Genetic diversity for environmental variability within the cultivated species of Avena. Crop Sci. 5:47-50

29. Prine, G. M. and G. W. Burton. 1956. The effect of nitrogen rate and clipping frequency upon the yield, protein content and certain morphological characteristics of Coastal bermudagrass, Cynodon dactylon (L.) Pers. Agron. Jour. 48:296-301.

30. Rai, S. D., F. C. Hinds, H. R. Isaacson, and G. E. McKibben. 1971. Notes: Digestibility of mechanical mixtures of early and late cut tall fescue. Agron. Jour. 63:653-654.

31. Ross, W. M. 1965. Yield of grain sorghum (Sorghum vulgare Pers.) hybrids alone and in blends. Crop Sci. 5:593-594.

32. Steel, G. D. and H. J. Torrie. 1960. Duncan's new multiple range test in "Principles and Procedures of Statistics". McGraw-Hill, Inc. New York. pp. 107-109.

33. Sullivan, J. T. 1962. Evaluation of forage crops by chemical analyses. Agron. Jour. 54:511-515.

34. Tilly, J. M. A. and R. A. Terry. 1963. A two stages technique for the in vitro digestion of forage crops. Jour. Brit. Grassl. Soc. 18:104-111.

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