BERMUDAGRASS DRY MATTER YIELDS AS AFFECTED BY NITROGEN FERTILIZER, HARVEST FREQUENCY, CLIPPING HEIGHT, AND CULTIVARS

by

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ABSTRACT

Dry matter production was determined from several bermudagrass cultivars receiving certain treatments. Coastcross 1 and giant bermudagrass were tested in the greenhouse under two watering regimes (500 and 1000 ml/pot weekly), two nitrogen levels (300 and 450 kg/ha), two harvest intervals (4 and 6 weeks) and two clipping heights (2.5 and 5 cm above soil surface). Coastcross 1 and Giant hybrids B442 x B445, B442 x Yakima and B442 x I-77-1 were tested in the field with regard to nitrogen fertilization (150 and 300 kg/ha), harvest interval (3 and 6 weeks) and clipping height (2.5 and 5 cm above soil surface) influences.

Dry matter production from all cultivars was highest under high watering regimes, at high nitrogen levels, with long harvest intervals. There was no consistent effect of clipping heights.

In the greenhouse, Coastcross 1 outyielded unselected giant bermudagrass under all treatments with lower sensitivity to close clipping. In the field study, Giant hybrids equaled or surpassed Coastcross 1 under certain management conditions showing the improvements brought about by selection and hybridization on the yield potential of giant bermudagrass.

INTRODUCTION

Bermudagrass, Cynodon dactylon (L.) Pers., a species complex of warm-season, sod-forming, perennial grasses, is widely distributed over the tropical and subtropical areas of the world. It propagates by seeds, stolons, and rhizomes. It has been recognized and accepted as an excellent, summer-growing, permanent pasture grass for much of the southern half of the United States.

Cynodon dactylon, according to Harlan et de Wet (1970), includes six distinct botanical varieties, among them dactylon (bermudagrass), aridus and afghanicus. The variety aridus is the giant bermudagrass in the U.S. seed trade. Variety afghanicus is similar to giant but lacks rhizomes.

The productivity of bermudagrass is a function of the species' genetic make-up and of management factors. Such factors are fertilization, soil moisture availability, and the harvesting process. The objective of this research was to study the production of bermudagrasses in terms of dry matter yield as affected by nitrogen fertilization, watering level, harvest interval, clipping height, and genotype.

LITERATURE REVIEW

Management Factors Affecting Productivity

Nitrogen Fertilization

Bermudagrass forage production depends primarily on the growing reproductive tillers which generally require adequate and sufficient nutrients for bud growth stimulation and activation. Increased fertilization increases not only total yield but nutritive value of forage as well (Holt et al., 1951). Nitrogen is the most important nutrient and the limiting factor to most growth. Increased bermudagrass production in response to nitrogen fertilization is due to an increase in number of leaf shoots, and in size and weight of each leaf shoot (Sell, 1944; Rathore et al., 1977). In addition Sell (1944) reported that protein content was increased by nitrogen application. In Virginia, Hallock et al. (1965) studied the performance of 'Coastal' bermudagrass (*Cynodon dactylon* (L.) Pers. var. *dactylon*) and certain cool-season grasses such as tall fescue (*Festuca arundinacea*, Schreb.), orchardgrass (*Dactylis glomerata* L.), and bluegrass (*Poa pratensis* L.) in response to nitrogen fertilization. Coastal bermudagrass gave more response to nitrogen than the cool-season species mentioned yielding about twice as much dry matter and protein as fescue at each level of nitrogen fertilization. Furthermore, Coastal bermudagrass utilized high rates of nitrogen with more efficiency than fescue.

Thompson (1977), in north-west Arkansas, studied the effect of fertilizers and limestone on yield and winter kill of Coastal Bermudagrass. He reported that throughout the duration of the experiment, nitrogen had a marked effect on forage yields with 336 and 672 kg/ha producing much higher yields than no nitrogen. Potassium improved yields and contributed to 39% increase in yield by the 5th harvest season, an additional production of 3.74 tons/ha (Thompson, 1977). Through the 7th harvest season, hay yields continued to show marked response to nitrogen and to potassium as well. Thompson (1977) stated that potassium reduced winter kill on the treatments heavily fertilized with nitrogen. Limestone had no effect on forage yields but significantly increased winter survival as measured by percent ground cover.

In Georgia studies, increasing nitrogen application increased yields of dry matter, crude protein and vitamin A content but had no effect on the fiber percentage in the grass. Annual application of 450 to 675 kg N/ha plus adequate rates of phosphorus and potassium are required for best performance (Burton et al., 1963). Increasing the nitrogen rate from 0 to 1000 kg/ha annually increases hay yield, protein percentage, protein yield, stem, leaf and internode length and internode number in Coastal bermudagrass, but leaf percentage, seed head frequency and percent nitrogen recovery decrease (Prine and Burton, 1956; Burton and Devane, 1954; Mathias et al., 1978). Burton, Southwell and Johnson (1956) reported that the palatability of Coastal bermudagrass increased with nitrogen application up to 225 kg/ha and then tended to level off. They also reported a decrease in moisture content with increasing nitrogen fertilization up to 225 kg/ha and an increase in dry matter with added increment of N up to 675-1000 kg/ha then a decrease indicating that the very heavy rates adversely affected growth. This is in accordance with the results obtained by Adegbola et al. (1966) who found that sod plugs from plots fertilized with 560 kg/ha made the best regrowth, and the plot fertilized with 850 kg/ha and higher rates made least regrowth.

After nitrogen is applied to pasture plants, plant metabolism changes and results in an increase in the production of protoplasm, protein, and other organic nitrogen compounds essential to plant survival. This change in metabolic activity initially affects carbohydrate metabolism of the plant. The synthesis of other compounds which depends on the use of carbohydrate contributes to a depletion of carbohydrate reserves present in the storage areas. The regrowth potential of pasture types is enormously affected by carbohydrate depletion and results in yield and survival reduction (Adegbola et al., 1966).

Nitrogen Sources and Application Procedure

Not only the quantity of nitrogen applied affects yields, but also the fertilizer source, time and method of application. These factors all have affected nutrient uptake of bermudagrass (Burton and Devane, 1952; Morris and Celecia, 1962). In the humid southeastern United States, the application of 225 kg/ha in four split applications resulted in higher forage yield and greater nitrogen recovery than when the nitrogen was applied in the spring in one application (Burton and Devane, 1952). Coats (1957) reported similar results in Mississippi when only 67 kg/ha were applied. Morris and Celecia (1962) indicated that nitrogen applied in the fall produced the lowest annual yields as compared with nitrogen applied in 4 split applications during the growing season 8695 vs 11835 kg/ha forage. They also concluded that the most efficient fertilization practice for bermudagrass in terms of total yield is to apply nitrogen in 4 split applications with P and K applied annually in early April. Burton and Devane (1952) found that a single heavy application of nitrogen produced forage with a higher average protein content than did a split application. This was also shown by Morris and Celecia (1962). Frequent small applications of nitrogen give a more favorable distribution of forage over the season. The four split applications of nitrogen used by Morris and Celecia (1962) resulted in the most evenly distributed forage production. The nitrate-N content of the forage as reported was non-toxic to livestock grazing the forage when normal rates of nitrogen were applied in split application (McCreery et al., 1966).

In Louisiana, Barrios et al. (1979) studied the relationship between some nitrogen fertilizer sources, rates, application frequencies, and quality of 'Tifgreen' bermudagrass grown for turf. They found that activated sewage sludge (Milorganite) was superior to ammonium nitrate and ureaformaldehyde (uramite) at most rates and application frequencies. They also found that foliar concentration of N, P, K, Cu, and Zn above critical levels were associated with increased quality and yield. At comparable nitrogen application rates and frequencies, Milorganite generally resulted in higher foliar N concentration than ammonium nitrate, while ureaformaldehyde treated plots were intermediate.

Phosphorus and Potassium

Phosphorus (P) and Potassium (K) are two other important elements determining pasture performance, yield and quality. Bermudagrass was responsive to heavy rates of nitrogen but not highly responsive to other elements unless the soil is exceedingly low in them (Thompson, 1977; Morris and Celecia, 1962). Emergence of grasses in the spring is enhanced by P while K increased winter hardiness at high rates of nitrogen (Sturkie and Rousse, 1968; Rousse, 1968). Rousse (1968) established that Coastal bermudagrass and other grasses were subject to fungal disease attack when available K was below the amount required for top production at the available N rates and moisture levels.

The total available carbohydrate (T.A.C.) production increases with increasing K fertilization. Under low K conditions, the soluble carbohydrate percentage increases due to the reduced polymerisation of single sugars, low rates of protein synthesis or reduced activity of enzymes involved in converting carbohydrates to other organic compounds (Hojjati et al., 1968). Protein production in response to fertilizer rates varies with the kind of fertilizer and application rate (Holt et al., 1951). These authors, working in Texas, reported an increase in protein production in both common and Coastal bermudagrass in response to N and P application. They indicated that the protein per acre for common and coastal was, respectively, 118 and 210 kg/ha when no fertilizer was applied, 135 and 250 kg/ha when 90 kg P/ha was applied, 360 and 430 kg/ha when only 90 kgN/ha were applied, and 408 and 412 kg/ha when 90 kg N and 90 kg P were applied per hectare. Holt et al. (1951) added that N application alone (135 kg/ha) increased the yield of protein in Coastal bermudagrass from 270 to 675 kg/ha while 135 kg N and 135 kg K/ha, produced 915 kg protein/ha, 135 kg N plus 135 kg P/ha produced 1000 kg protein/ha and the application of a combination of all three elements resulted in still higher production, 1120 kg protein/ha.

The time of application of P and K is important. Fall application of P and K in Cecil sandy loam was less efficient than the conventional spring application and contributed to lower annual forage production (Morris and Celecia, 1962). The productivity and performance of grass species are accordingly determined by the level of available nutrients in the soil.

Harvest Management

Effects of Clipping Interval on Yield

Frequency of herbage removal greatly influences the amount dry matter produced. Burton et al. (1963) reported that annual forage yields of Coastal bermudagrass at Tifton, Ga, increased as the interval between cuttings increased to 12 weeks and dropped sharply in plots harvested only once a year. In a clipping study over a 3-year period, 15.2 metric tons of forage/ha were obtained with 3-week cut, but 20 metric tons/ha with 6-, 8- and 12-week cuts. Production dropped significantly to 15 metric tons forage/ha, when the grass was cut only once a year. Prine and Burton (1956) found that increasing the clipping interval from 1 to 8 weeks increased hay yield, stem length, leaf length, plant height, and seed head frequency of Coastal bermudagrass, but had little effect on protein yield and percent nitrogen recovery. Burton (1954) reported that the hay production corresponding to 2-, 3-, 4-, 6- and 8-week clipping intervals of Coastal bermudagrass was 12.5, 15, 19, 24, 25 metric tons/ha, respectively. An 8-week-interval between harvests compared to 4 weeks increased the total dry matter harvests compared to 4 weeks increased the total dry matter production for both Coastal and 'Coastcross' bermudagrass in Tifton, Ga, by about 39%, but only by 9% for 'Pensacola' bahiagrass (Paspalum notatum Flugge). The 4-week-interval contrasted to the 8 weeks increased the crude protein, ether extract and ash content of the material; but, nitrogen free extract, crude fiber, cellulose, acid detergent fiber, acid detergent lignin and cell wall content were all considerably lower in the younger forage (Utley et al., 1971).

Frequent removal of the tops inhibits root growth (Harrison, 1931; Graber, 1931). There is greater tillering, better recovery, and more vigorous growth on plots cut less frequently because sufficient leaf area develops and enough carbohydrate is synthesized and translocated to build up strong crowns and root systems (Wilsie et al., 1940; Wright et al., 1967; Jung et al., 1974; Kunelius, 1979).

Effect on Quality

Frequency of clipping is important in determining the quality of hay produced by any forage crop. Coastal bermudagrass harvested at three different forage ages (4, 6 and 8 weeks) on five different dates in Louisiana, showed that crude protein, cell wall constituents, acid detergent fiber, cellulose, acid insoluble lignin and in vitro dry matter digestibility were affected by harvest date and age (Nelson et al., 1980). Burton et al. (1956) reported that a 2 week-old grass is more palatable, more succulent, less productive and higher in protein content than a 4 week-old grass. Generally, palatability, protein content, and digestibility are reduced as the clipping time is delayed (Burton, 1954). Burton (1954) reported that the average protein contents of Coastal bermudagrass cut at the frequency of 2-, 3-, 4-, 6-, and 8-week intervals was 17.4, 16.6, 15.2, 11.3 and 10.3%, respectively. Cellulose content of Coastal bermudagrass increased from 28.7% for 3-week old grass to 32% when grass was cut every 6 weeks. The digestible dry matter dropped consistently from 65.2% for 3-week old grass to 43.2% for grass cut only once a year. The digestible crude protein ranged from 73.6% for 3-week old grass to 48.1% for 24-week old grass (Burton et al., 1963). Dittmer (1973) found that the higher bermudagrass was allowed to grow, the greater the weight of both roots and tops but the root/shoot ratio remained constant at about 40% roots to shoots. Beaty et al. (1980) concluded that close clipping or grazing will increase digestibility by keeping the forage green, increasing the effective yield of pastures. The optimum frequency of clipping, however, would depend on whether quantity or quality of forage was the primary objective. Brown et al. (1976) studied the performance of bermudagrass cultivars and bahiagrass in Southern Mississippi. They found that under a two-week harvest, forage production declined from 16 to 22% as compared to the 4-week interval. Crude protein averaged significantly higher in forage cut every 2 weeks (18%) than the forage cut every 4 weeks (16.1%).

Effect of Clipping Height on Dry Matter Production

The influence of clipping height on dry matter yields is variable with no consistent significant trend. As stated by Blaser (1946), Watkins (1940), and Watkins et al. (1951) height as well as frequency of cutting influenced yield and quality. No standard clipping management technique has been developed because of differences in morphological characteristics and growth habits of the various pasture species. In general, as the clipping height increases, forage production decreases. Forty percent of the forage produced is within 2.54 cm of the soil surface, an additional 16 to 18% is produced between 2.54 and 5.08 cm from the surface (Stanley et al., 1967; 1968 and Blaser, 1946). Stanley et al. (1967) found that regrowth of Pensacola bahiagrass was highest when it was clipped to 5.08 cm or less and lowest when the grass was allowed to grow to 10.16 cm or more. Caro-costas et al. (1981) reported that 'Stargrass' (<u>Cynodon nlemfuensis</u> Vanderyst) pastures performed similarly under 3 different grazing intervals (14, 21, and 28 days) provided that they were grazed no closer than about 20 cm from the ground and that they were well fertilized. Grazing no closer than 20 cm left sufficient photosynthetic area and enough root reserves to ensure rapid regrowth of the grass after grazing. Grasses fertilized with adequate amounts of nitrogen tended to produce a higher percentage of forage above 5.08 cm than did grasses receiving no nitrogen (Stanley et al., 1967). In addition, these authors reported that nitrogen application to bahiagrass pastures tended to slightly increase the forage produced above 12.07 cm and to decrease the percentage produced below 5.08 cm.

Environmental Effects

Soil Moisture

Plant response to fertility is limited by soil moisture availability and yield responses are favored by adequate subsoil moisture. Bermudagrass stolons under arid and low nitrogen conditions are thickened and woody and bear fewer and smaller leaves having shortened leaf sheaths, but under fertile and moist conditions, the stems are small but have large leaves (Day and Jordan, 1961). Barton, Baker and Jung (1968) studied the effect of environmental conditions on the growth of perennial grasses; timothy (Phleum pratense L.), orchardgrass, smooth bromegrass (Bromus inermis Leyss), and Kentucky bluegrass. They reported a decrease in yield when fertilizer was added when there was a low water supply and/or high temperature. Supplemental irrigation during periods of low rainfall increased yield and nitrogen recovery of warm-season grasses such as Coastal bermudagrass, Pensacola, bahiagrass, and dallisgrass (Paspalum dilatatum Poir.); however, the recovery percentage of applied nitrogen recovered decreased as nitrogen rates increased and was highest on Coastal bermudagrass (Ashley et al., 1965). As stated by Doss et al. (1966), the nitrogen rates and moisture availability interaction showed that nitrogen was more important than moisture regimes in increasing yields of bermudagrass. They also concluded that clipping frequency interacted with moisture and nitrogen rates. Yield differences due to clipping intervals were greater at high soil-moisture regimes and high nitrogen rates. Nitrogen content of the above ground portion was only affected by nitrogen supply rates and clipping intervals. Reichman and Grunes (1966) also reported a response to soil moisture and an increase of dry matter yield as soil moisture increased.

Irrigation decreases the percentage of total available carbohydrate (TAC) but increases TAC production/ha because forage yield increases. Watering stimulates the top growth of grasses which enhances the use of carbohydrate by individual plants (Hojjati et al., 1968).

Temperature

Plants respond differently to varying temperatures. The temperature of a turfgrass plant or its parts is determined by the total environmental factors that affect energy exchange. Such environmental factors include light intensity, thermal radiation, air temperature, atmospheric water vapor content and wind (Beard, 1973). Species from warmer native habitats generally have higher temperature optima. The optimum temperature range for warm-season grasses as reported by Beard is 26 to 35 C for Zoysiagrass (Zoysia japonica Steud), manilagrass (Z. matrella (L.) Merr.), carpetgrass (Axonopus affinis Chase), and bermudagrass. He also reported that shoot growth decreases as temperatures are decreased or increased from the optimum range. Tillering, succulence, leaf number, leaf width, leaf length, leaf area and new leaf appearance rate have an optimum temperature range similar to the optimum temperature range for shoot growth. Shoot growth of 'U-3' bermudagrass ceases at mean daily soil temperatures of approximately 10 C or lower. Bermudagrass can maintain its shoot growth as well as its color at night temperatures as low as 1.1 C provided that day time temperatures are 21 C or higher (Beard, 1973). 'Midland' bermudagrass survived a low temperature of -29 C and withstood high summer temperatures under low moisture conditions (Mathias et al., 1978). The optimum temperature range for root growth of warm-season grasses ranges from 24 to 29.5 C and total root growth ceases as soil temperatures are either decreased or increased from the optimum range (Beard, 1973).

According to Beard, apparent photosynthesis under low light intensity reaches maximum rates at 35 C for common bermudagrass. The optimum temperatures for photosynthesis, respiration and apparent photosynthesis are significantly higher than the optimum temperatures range for shoot and root growth, and warm-season turfgrasses have a higher optimum than cool-season species (Beard, 1973).

Salinity

Soil salinity, as mentioned by Thomas and Langdale (1980), interacts with nitrogen fertilizer. Forage and protein yields of coastal bermudagrass grown on moderately saline soil were enhanced by a nitrogen fertilizer-soil salinity interaction. It was suggested that the interaction effects might be associated with the cation-anion balance. Nitrogen and salinity treatments significantly affected dry matter yield and the chemical composition of the foliage. Nitrogen fertilization increased the concentration of K, Ca, Mg, NO_3, Cl, SO_4, and organic nitrogen in Coastal bermudagrass. Increased soil salinity significantly increased the concentration of cations (except Ca decreased), inorganic anions and organic nitrogen in the grass. Dry matter yields increased with an increase in the concentration of cations at all salinity levels.

Acidity

Soil acidity affected bermudagrass growth when pH was below 5.5. Research has shown that chemical soil test values can be related to crop response in the field and to rate of application of minerals needed to prevent limiting yield (Rousse, 1968).

Handling of Planting Material

It is another factor would be of great importance and consideration when establishing bermudagrass pastures. The method of sprig storage and planting depth affect the regrowth potential and sprouting of bermudagrass ecotypes. Wet stored sprigs have higher average percent sprouting of both sprigs and buds. In contrast, dry storage reduces moisture content, vigor of sprouts, and the number of sprouting buds throughout a 16 day-period. Less mold growth and disease damage developed with wet storage conditions. When planting depth increased from 1 to 4 inches, a delay in emerging sprouts and a decrease in the percent of sprouting sprigs were observed (Chiles et al., 1966).

Bermudagrass without fertilization and adequate management, like other perennial crops, will decline in yield and stand from year to year until a very low level of production is reached. A better understanding of the species and its response to cultural and environmental conditions should lead to more effective manipulation and consequently to improved yields.

Genotypic Effects on Productivity

Bermudagrass breeding began as early as 1937 with work conducted and achieved by Glenn W. Burton at Tifton, Ga (Burton, 1947). Breeding programs were established to develop more productive bermudagrass strains capable of supplying highly nutritious and palatable forage during a greater portion of the year. Resistance to disease, drought, and frost injury were some of the specific features sought (Burton, 1947). Thousands of crosses have been made to meet the desirability of creating tall growing types suitable for hay production and to develop adapted, high yielding, and high quality bermudagrass trains (Taliaferro, 1974; Burton, 1947; Holt et al., 1979). Cultivars released for forage production include Common, Midland, 'Suwannee', Coastcross 1, and 'Tifton 44'. Research at Oklahoma has produced 'Oklan' and 'Hardie' for forage production, quality and stand persistency (Taliaferro and Richardson, 1976). The development of new hybrids or varieties is facilitated by two characteristics of bermudagrass: high level of self sterility and easy vegetative propagation (Burton, 1947; Kneebone, 1972). All of the listed cultivars are vegetatively propagated.

Strain evaluation tests were and still are run to evaluate advanced breeding lines and newly released bermudagrass cultivars (Burton, 1954; Holt et al., 1951; Cooper and Burton, 1965; Taliaferro, 1974; Taliaferro and Richardson, 1976; Taliaferro and Alexander, 1977; Burton and Hanna, 1977; Holt et al., 1979; Andrews et al., 1979).

Studies of selected cultivars in comparison with each other and with common bermudagrass have shown significant differences in terms of yield, digestibility, and animal gain. In Georgia, Stephens (1952) conducted a strain evaluation study with respect to Common, Suwannee, Coastal, and 'Tift' bermudagrass cultivars. He reported that Common bermudagrass although recognized as a fairly good pasture species has two draw backs; low yield and production of abundant seed heads early in summer. Because of its reduced vegetative growth, its nutritive value and palatability are reduced. Tift bermudagrass comparatively has a long growing season and it was the first tall-growing bermudagrass adapted for grazing and for hay. Coastal bermudagrass, a hybrid produced from crossing an African introduction of bermudagrass and Tift bermudagrass, has considerable hybrid vigor and tolerates more frost, makes more growth in late summer and fall. It is more resistant to drought and Helminthosporium leaf disease. Suwannee bermudagrass is another hybrid that resembles Coastal but has darker green leaves, more erect stems and is better adapted to light sandy soils of lower fertility. Utley et al. (1971) studied the comparative feeding value of Coastal, Coastcross 1 bermudagrass, and Pensacola bahiagrass. They reported that Coastcross 1 (Coastal X Kenya 54 # 14) yielded as much per hectare as Coastal bermudagrass, but had greater dry matter digestibility, greater apparent digestibility for all fibrous constituents, and provided faster gain per steer than Coastal bermudagrass.

Midland bermudagrass, a winter-hardy cross between Coastal and a strain from Indiana, showed better performance than did Coastal along the northern edge of the bermudagrass belt (Decker et al., 1971). Brown et al. (1976) studied the performance of 5 warm-season grasses including Common, Coastal, and Coastcross 1 bermudagrass. They reported that Coastcross 1 was higher than Coastal and common varieties in total dry matter in the first year but declined 18% the year after and was significantly higher in dry matter digestibility in both years followed by Coastal and common. Tifton 44, resulting from a cross between Coastal and another strain surviving in Berlin, Germany, was 5 to 6% more digestible than Coastal bermudagrass (Burton et al., 1978). In Dixon, Illinois, a strain evaluation study was conducted through the period 1974-1979 with regard to Georgia experimental hybrids 72-4, 72-29, 72-44 (Tifton 44), 72-45, 72-50, 72-51, 72-77, 72-81, 72-84, and Callie, Coastal, Coastcross 1, Midland, Hardie and a Southern Illinois ecotype 'Elsberry' (Faix et al., 1981). They reported that under 4- to 6-week harvest intervals, 11 of 17 bermudagrass entries yielded an average of 18.5 to 30 metric tons/ha dry matter annually. Georgia hybrids 72-44 and 72-45 provided high yield, good seasonal yield distribution and were undamaged by winter from 1974 to 1977, but after two subsequent hard winters, their spring recovery was markedly delayed. Hardie and Midland presented vigorous spring growth but reduced summer production caused by leaf disease. In vitro digestibility for the listed bermudagrasses ranged from 43.8 to 50.6%. Faix et al. (1981) came to the conclusion that Tifton 44 and hybrid 72-45 which were resistant to leaf disease could improve summer forage production in the transitional climatic zone of U.S.A.

MATERIALS AND METHODS

This study was conducted in two parts: part A, a greenhouse study, and part B, a field study.

Part A

This experiment was conducted in two adjoining greenhouses on campus at the University of Arizona, Tucson, Arizona, to evaluate the performance of two bermudagrass cultivars under certain management conditions.

Plant Materials and Methods

Plugs, 10 cm in diameter and 10 cm deep, of Coastcross 1 bermudagrass, (*Cynodon dactylon* (L.) Pers. var *dactylon*), and giant bermudagrass, (*C. dactylon* (L.) Pers. var *aridus*) (Harlan et de Wet) were taken from established sods. Giant plugs were collected from the University of Arizona Rincon Vista Turfgrass Research Center, Tucson, Arizona, and Coastcross 1 plugs were collected at the Maricopa County Agricultural Extension Office, Phoenix, Arizona. Plugs were then potted in black, 4-liter plastic pots filled to 4/5 of their volume with a mixture of 50% washed mortar sand and 50% silt-loam soil. Sixty-four pots were established from each cultivar. The experiment was conducted in two greenhouses with two complete sets of each cultivar with all treatment combinations completely randomized in each set in each house. The two greenhouses had different temperature settings, 16 and 27 C. Potted plugs were placed in the greenhouses September 6, 1980 for a 25-day establishment period. Plants in pots were clipped evenly at the height of 2 cm above soil level on October 2. Treatment differentials were initiated on October 3.

The treatments involved were: two harvest intervals (4 and 6 weeks), two clipping heights (2.5 and 5 cm above soil level), two watering regimes (500 and 1000 ml per pot weekly), and two nitrogen levels (300 and 450 kg/ha). Nitrogen was applied after each clipping at the rate of 50 and 75 kg/ha. Application rates were adjusted to the frequency of clippings in order to provide the plants with the assigned level of nitrogen for the growing period. The nitrogen source was urea 46-0-0.

Harvested samples were oven dried and weighed to determine dry matter yields. Stand increase ratio was also determined by estimating the stand cover at the time of the first harvest and the stand at the last harvest. The final/initial stand ratio gave the stand increase percentage in response to the different treatments. The number of harvests achieved from November 6 (first date of sampling) until March 12 (last harvest made) were six for the 4-week and four for the 6-week harvest intervals.

Part B

Coastcross 1 bermudagrass and three sources of giant bermudagrass were sprigged by hand on June 5, 1980 at the University of Arizona Campbell Avenue Farm, Tucson, Arizona in an Agua loam soil (mixed calcareous thermic typic torrifluvents). The giant bermudagrasses were randomly sampled plants from each of three experimental hybrid progenies: B442 X B445, B442 X Yakima, B442 X 1-77-1. The progeny plants were grown as spaced plants at the University of Arizona Casa Grande Highway Farm, Tucson, Arizona. Plant material was dug, separated into sprigs, and plants within each progeny were mixed together for planting. The Coastcross 1 material came originally from a planting at the Maricopa County Agricultural Extension Office, Phoenix, Arizona. Material from this source was increased in flats for planting. Identification and origins of clones involved as parents of the giant bermudagrass hybrid progenies are given in Table 1.

Five replications were established. The experimental design was a split-plot arrangement in which the main-plot treatments were grasses. Half of each replicate was harvested at 3-week intervals and half at 6 weeks. Each subplot of grass and harvest interval had the following treatments randomly distributed and applied within it: two clipping heights (2.5 and 5 cm above ground) and two nitrogen levels (180 and 360 kg N/ha) applied at the rates of 30 and 60 kg/ha after each clipping (including the first cut made before initiation of treatments). Each treatment combination plot area was 2 m^2. Yield samples were harvested with a hand sickle from 0.25 m^2 areas randomly chosen within each treatment area. One such sample was taken from each plot at each cutting, oven dried, and dry weight recorded.

The nitrogen source was ammonium sulphate 21-0-0. Application rates of nitrogen were adjusted according to the clipping interval to supply the assigned amount of fertilizer to growing plants.

Table 1. Origin of parent clones for giant bermudagrass progenies grown in field study.

Clone	Variety*	Origin
B442	_C._ _dactylon_ (L.) Pers. var. _afghanicus_	Herat, Afghanistan (P. I. 223129)
B445	_C._ _dactylon_ (L.) Pers. var. _aridus_	Buffelsvlei, S. Africa (P. I. 291616)
Yakima	_C._ _dactylon_ (L.) Pers. var. _aridus_	Yakima, Washington
I-77-1	_C._ _dactylon_ (L.) Pers. var. _aridus_	Unknown, seedling selection, Tucson, Arizona.

*Using classification of Harlan et al. (1970).

Plots were clipped evenly on May 10 and differential treatments were initiated May 12.

RESULTS AND DISCUSSION

Dry Matter Yields from Greenhouse Study

Forage production was significantly affected by water regimes, nitrogen fertilization rates, harvest interval, clipping height, and cultivars (Table 2). A difference of temperature of 11 C between the two greenhouses appeared of no significant influence on bermudagrass performance, since there was no significant variation among replicates of each treatment. Coastcross 1, for example, yielded 9060 and 8997 kg dry matter/ha, respectively, in the two greenhouses at the 450 kg N/ha and 6-week cutting interval.

The only significant interaction effects on dry matter yield were those involving cultivars and water regimes with harvest intervals (Table 2).

The mean dry matter yield obtained from the entire population was 7050 kg/ha. Coastcross 1 outyielded Giant 7475 vs 6624 kg/ha (Table 3). Plants supplied with 1000 ml water weekly performed better as shown by higher dry matter yields than plants receiving only 500 ml water weekly (Table 4). Plants receiving 450 kg N/ha produced more forage dry matter/ha than those receiving only 300 kg N/ha (7473 vs 6623 kg/ha, (Table 5). Although Coastcross 1 outyielded Giant at both nitrogen levels, there was less advantage at the higher fertility level indicating greater nitrogen response potential in the giant. Coastcross 1 produced 7334 and 7612 kg/ha compared with 6293 and 6953 kg/ha for giant at 300 and 450 kg N/ha, respectively (Table 5).

Table 2. Summary of significant treatment effects as demonstrated by analysis of variance for dry matter production for the greenhouse study.

Treatments	Significance by F Test
Water regimes	**
Nitrogen rates	**
Harvest intervals	**
Clipping heights	*
Cultivars	*
Cultivar x interval	*
Water x interval	**
Cultivar x water x interval	*

* Significant at the 5% level
**Significant at the 1% level

Table 3. Dry matter yields as affected by cultivars and harvest intervals for the greenhouse study.

Cultivars	Harvest Intervals 4 weeks	 6 weeks	 Mean
	Dry matter yields kg/ha		
Coastcross 1	6427*	8703	7475**
Giant	5761	7488	6624
Mean	6004#	8095	7050

* LSD$_{.05}$ for cultivar x harvest interval means = 466.6

**LSD$_{.05}$ for cultivar means = 328

\# LSD$_{.05}$ for harvest interval means = 328

Table 4. Dry matter yields as affected by cultivars, harvest intervals and water regimes for the greenhouse study.

Cultivars and Harvest Intervals	Water Regimes 500 ml	1000 ml	Mean
	Dry matter yields kg/ha		
4-week intervals			
Coastcross 1	5838*	6656	6427**
Giant	5108	6414	5761
4-week mean	5473#	6535	6004
6-week intervals			
Coastcross 1	7294	10112	8703
Giant	6513	8462	7488
6-week mean	6903	9287	8095

* LSD $_{.05}$ for cultivar x harvest interval x water regime means = 656

**LSD $_{.05}$ for cultivar x harvest interval means = 466.6

\# LSD $_{.05}$ for harvest interval x water regime means = 466.6

Table 5. Dry matter yields as affected by cultivars, nitrogen levels and clipping heights for the greenhouse study.

Cultivars	N levels	Clipping Heights 2.5 cm	5 cm	Mean
		Dry matter yields kg/ha		
Coastcross 1	300 kg/ha	7251*	7420	7334**
	450 kg/ha	7527	7696	7612
Mean		7389#	7558	7473
Giant	300 kg/ha	5992	6594	6293
	450 kg/ha	6652	7254	6953
Mean		6322	6924	6623

* LSD $_{.05}$ for cultivars x nitrogen level x clipping height means = 660.2

**LSD $_{.05}$ for cultivars x nitrogen level means = 466.6

LSD $_{.05}$ for clipping height x nitrogen level means = 466.6

The influence of harvest intervals was highly significant with highest dry matter production at the 6-week cutting intervals. Plants cut every 6 weeks produced 8096 kg/ha compared with 6004 kg from plants cut every 4 weeks (Table 3). Coastcross 1 cut every 4 weeks produced more, but not significantly so, than Giant cut at the same frequency. When cutting interval was increased to 6 weeks, the difference among cultivars was greater and highly significant (486 kg/ha with 4-week intervals and 1215 kg/ha with 6-week intervals) (Table 3).

Dry matter yields were affected by clipping height. The closer the clipping, the less forage produced. Plants cut at 2.5 and 5 cm above ground yielded 6855 and 7241 kg/ha, respectively. Giant bermudagrass showed more sensitivity to severe clipping than Coastcross 1 and recovered more slowly. Dry matter yields obtained from Coastcross 1 cut at 2.5 and 5 cm above ground were 7389 and 7558 kg/ha, respectively. For the same cutting heights, Giant produced 6322 and 6924 kg/ha, respectively (Table 5).

The highly significant interaction between water regimes and clipping intervals is illustrated by a yield increase of 2752 kg/ha for the 6-week interval over the 4-week interval under 1000 ml watering compared with 1430 kg increase under 500 ml watering regime (Table 4). Differences of 1818 and 2456 kg/ha were recorded with Coastcross 1 due to watering regimes and cutting intervals, respectively (Table 4). The higher water regime and longer clipping interval gave more production with Coastcross 1 than with Giant (10112 vs 8462 kg/ha, Table 4). Coastcross 1 receiving 1000 ml water weekly showed more response to clipping interval than Giant receiving the same amount of water (3456 vs 2048 kg/ha, Table 4). Coastcross 1 cut every 6 weeks showed better performance than Giant when supplied the higher water rate (2818 vs 1949 kg/ha, Table 4).

In general and for better performance of species, their growing conditions should be well understood. Giant as well as Coastcross 1 had higher dry matter yields when cut less frequently, provided with adequate moisture and with sufficient nitrogen. Giant, however, was more severely affected by close mowing than Coastcross 1.

Stand

Stand increase ratio is directly related to vegetative growth which generally requires adequate and sufficient nutrients as well as moisture to stimulate and activate bud growth. Griffith et al. (1965) found that low mowing and high nitrogen rates contributed to stand reduction. Through the period of this study a few pots had decreased stand, although the differences were not significant as far as the involved factors were concerned. The pots showing stand reduction were observed with Giant cut every 4 weeks and at the height of 2.5 cm above ground. A reason for the non significant difference of stand between pots and among treatments could be the fact that the volume of soil as well as the area devoted to root development and tillering were not adequate to allow full expression of treatment effects. Final stands were 126.1 ± 26.5% of initial stands.

Dry Matter Yields from Field Study

Forage production from the Giant hybrids and Coastcross 1 was significantly affected by harvest interval, nitrogen level and clipping height (Table 6). Total yields for the season from the Giant progenies and Coastcross 1 were similar and averaged 15880 kg/ha. Potential for yield improvement by selection and hybridization are shown by the similar yields from the giant hybrids and Coastcross 1 in the field study. In the greenhouse, the unselected giant was significantly outyielded by Coastcross 1. At the 3-week harvest interval and both nitrogen levels (180 and 360 kg/ha), Coastcross 1 had somewhat higher yields than the Giants, but the Giants equaled or surpassed Coastcross 1 under the 6-week harvest interval and particularly at the higher nitrogen levels (Table 7). This variation of response to nitrogen and harvest interval is graphically shown by seasonal values in Figure 1 and 2 using yields at the low clipping height (2.5 cm).

Plants cut every 6 weeks had significantly higher dry matter yields than those cut at 3-week intervals under all treatments (Tables 7 and 8). Giant progenies, under both nitrogen levels and both clipping heights showed a greater degree of response to the long harvest interval than Coastcross 1 either in terms of total dry matter yields or in terms of production from individual harvests (Figure 2 and 4). Coastcross 1, on the other hand, had greater response to close clipping and 3 week intervals than did Giant hybrids (Figures 1 and 3), especially under high nitrogen levels. The greenhouse study also has proven that Common giant was poorer at frequent harvests and close clippings (Tables 3 and 5).

Table 6. Summary of significant treatment effects as demonstrated by analysis of variance for dry matter production (Field study).

Treatments	Significance by F Test
Harvest interval	**
Nitrogen	*
Clipping height	*
Height x Nitrogen	*
Cultivar x Interval	*
Cultivar x Nitrogen x Interval	*

* F significant at the 5% level

**F significant at the 1% level

Table 7. Dry matter yields as affected by nitrogen fertilization, harvest intervals, and cultivars in the field study.

Cultivars and Harvest Intervals	Nitrogen Levels			
	180	360	increase kg/kg N	Mean
		Dry matter yields kg/ha		
3-week intervals				
B442 x B445	11061*	12727	9.3	11894**
B442 x yakima	10456	13872	19.0 $\bar{x}$=15.2	12164
B442 x I-77-1	10783	13924	17.4	12354
Coastcross 1	12210	15213	16.7	13712
3-week mean	11128#	13934	15.6	12530
6-week intervals				
B442 x B445	14974	22516	41.9	18745
B442 x yakima	17856	23374	30.7 $\bar{x}$=37.4	20615
B442 x I-77-1	15050	22174	39.6	18612
Coastcross 1	15109	22779	42.6	18944
6-week mean	15747	22711	38.7	19230

* LSD$_{.05}$ for cultivar x harvest interval x nitrogen level means = 1530

**LSD$_{.05}$ for cultivar x harvest interval means = 1080

\# LSD$_{.05}$ for harvest interval x nitrogen level means = 2760

Table 8. Dry matter yields as affected by cultivars and harvest intervals in the field study.

Cultivars	Harvest Intervals		
	3 weeks	6 weeks	Mean
	Dry matter yields kg/ha		
B442 x B445	11894*	18745	15320**
B442 x yakima	12164	20615	16390
B442 x I-77-1	12354	18612	15483
Coastcross 1	13711	18944	16328
Mean	12530#	19230	15880

* LSD $_{.05}$ for cultivar x harvest interval means = 1080

**LSD $_{.05}$ for cultivar means = 1960

\# LSD $_{.05}$ for harvest interval means = 1950

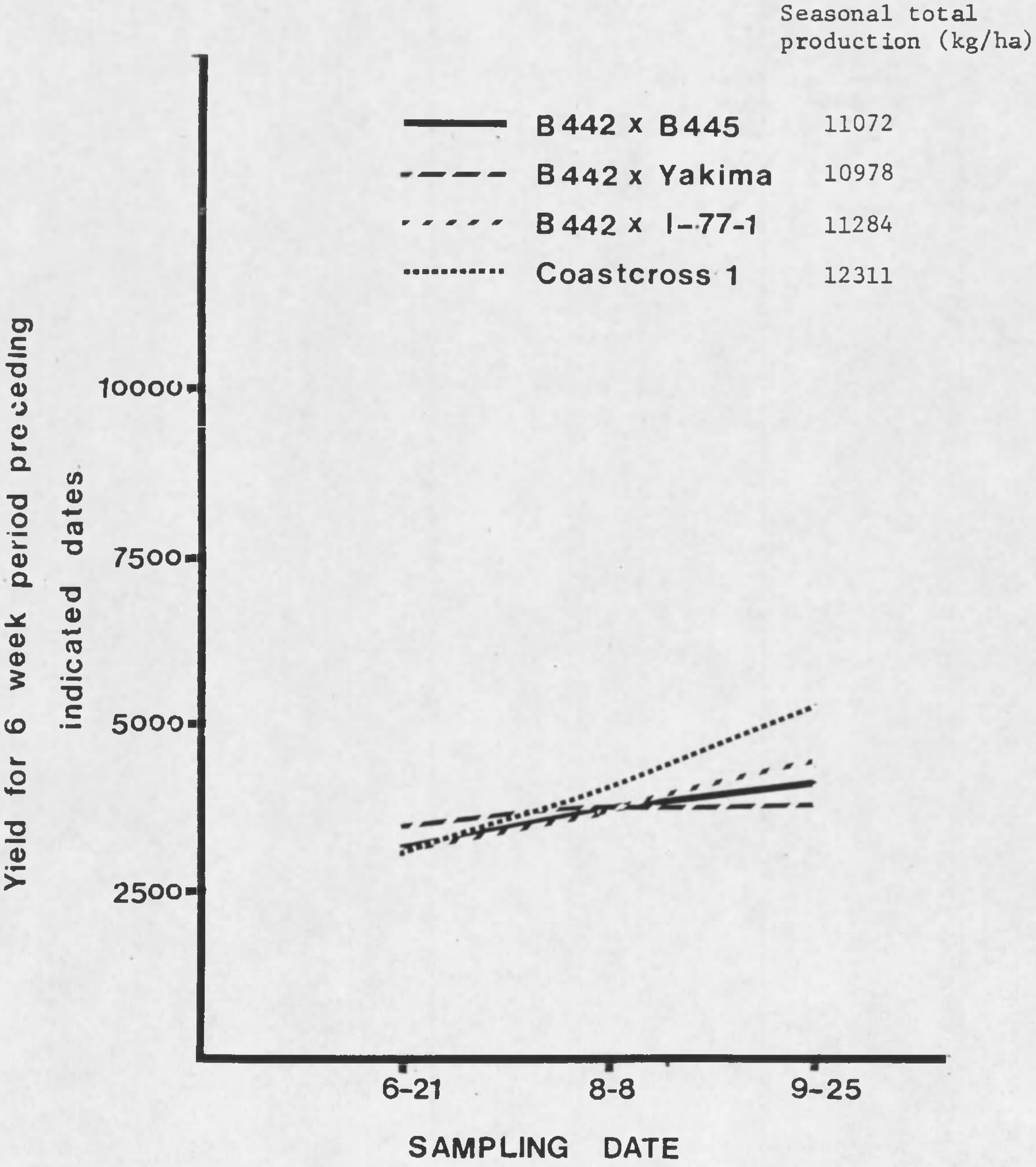

Figure 1. Performance of bermudagrass cultivars in response to low nitrogen fertilization, 3 week harvest interval and close clipping.

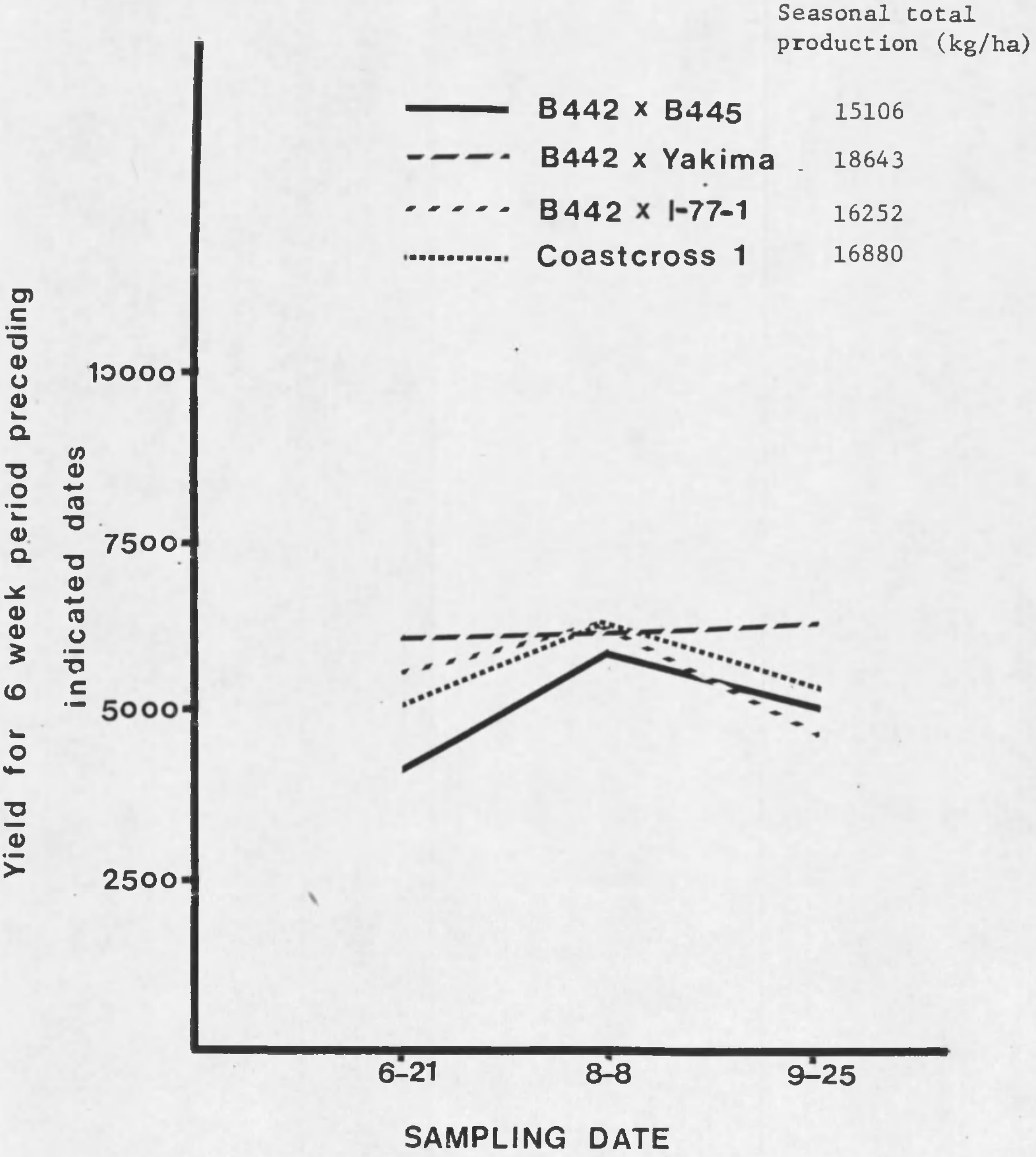

Figure 2. Performance of bermudagrass cultivars in response to low nitrogen fertilization, 6 week harvest interval and close clipping.

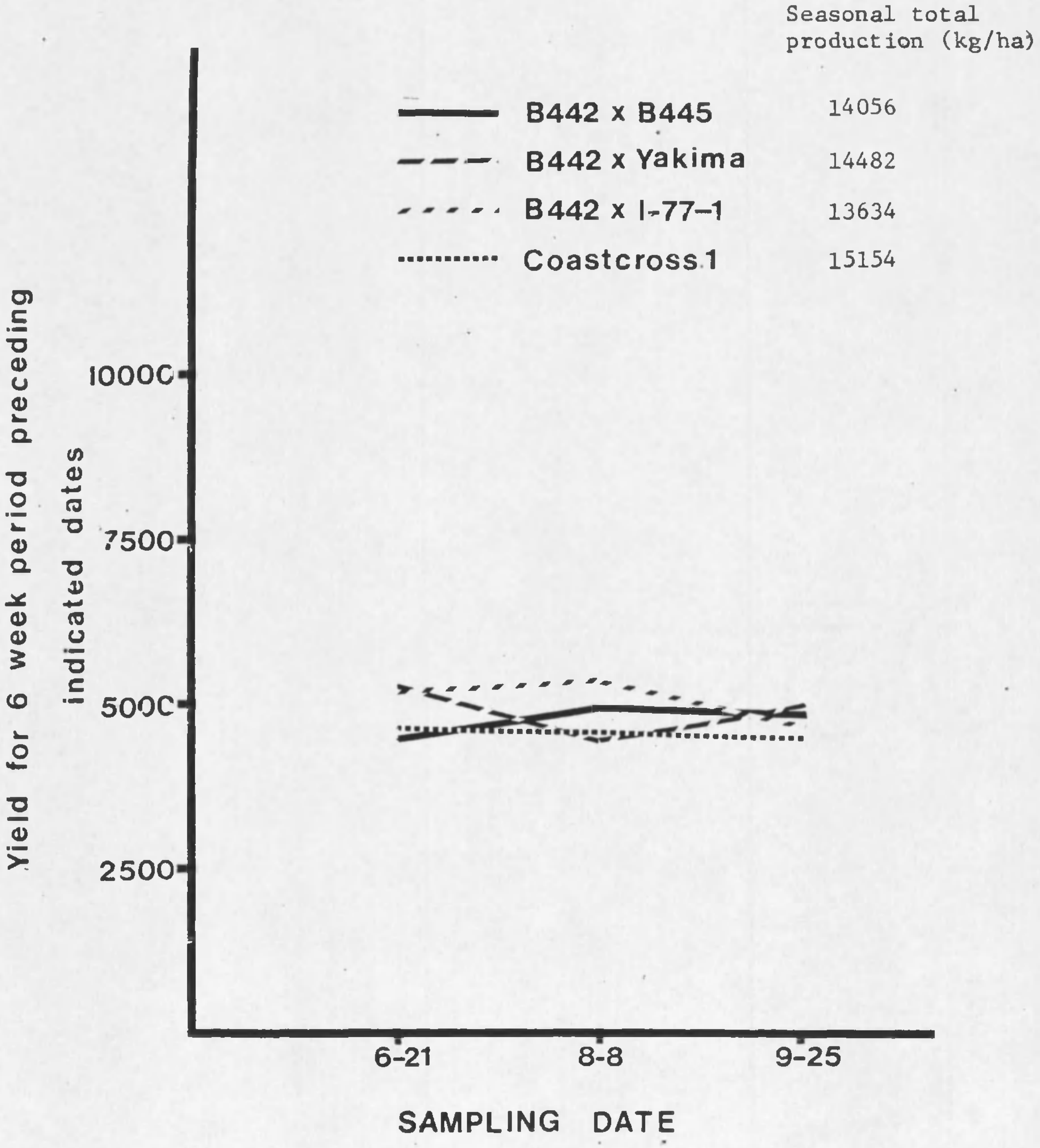

Figure 3. Performance of bermudagrass cultivars in response to high nitrogen fertilization, 3 week harvest interval and close clipping.

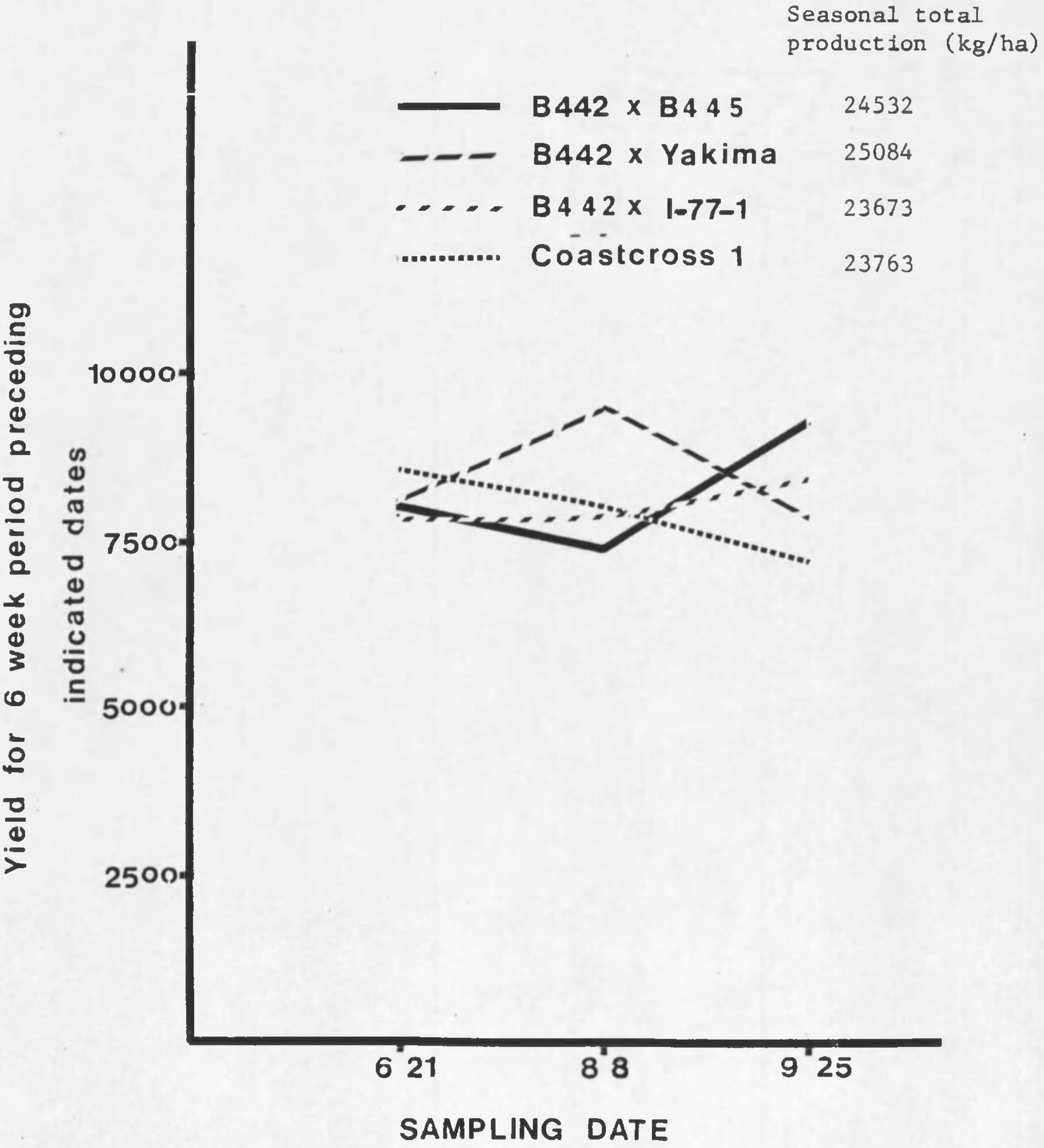

Figure 4. Performance of bermudagrass cultivars in response to high nitrogen fertilization, 6 week harvest interval and close clipping.

As shown in the greenhouse, and in published data from other areas, dry matter yields increased with longer intervals between harvests. In the greenhouse, Coastcross 1 showed greater response to 6-week harvest intervals than did Common giant and produced 2456 kg/ha more over the 4-week intervals compared with 1727 kg/ha from Common giant (Table 3). In the field, Giant hybrid B442 x Yakima outyielded Coastcross 1 at the 6 week harvest interval. B442 x Yakima cut at the 6 week intervals produced 8450 kg/ha more than when cut at 3 week intervals (20615 vs 12164 kg/ha, Table 7). Similar increases for the other giant hybrids averaged 6550 kg/ha and for Coastcross 1, 5320 kg/ha. Cultivar performances and responses tended to follow similar or slightly different patterns throughout the experiment period as shown graphically in figures 1, 2, 3 and 4.

Additional nitrogen fertilization, as expected and as shown by the greenhouse study, increased dry matter production of all bermudagrass cultivars, with Coastcross 1 showing a greater response than the giant hybrids, particularly at 6-week harvest intervals coupled with the 5-cm clipping height. In the greenhouse study, Common giant presented greater response to nitrogen rates than Coastcross 1 (4.4 vs 1.85 kg D.M/kg additional nitrogen), but Coastcross 1 produced more forage in response to higher fertilization. In the field, this higher efficiency did not persist with Giants, and Coastcross 1 presented a higher degree of response. The degree of response at the 3-week cuts averaged 15.2 kg/kg N for Giant hybrids with 19 and 16.7 kg/kg N for B442 x Yakima and Coastcross 1, respectively (B442 x B445 showed the least response; 9.3 kg/kg N). At the 6-week harvests, B442 x Yakima showed the least response to additional fertilization, and B442 x B445, comparatively, presented the greatest response among Giant hybrids (41.9 kg/kg N). The average response was 37.4 kg/kg N for Giants with 30.7 and 42.6 kg/kg N for B442 x Yakima and Coastcross 1, respectively (Table 7). This trend of response was observed throughout the study.

Dry matter production from plants cut at 2.5 cm above ground was higher than that from plants cut at 5 cm (Table 9). The difference of dry matter yields due to clipping heights was greater with Giant hybrids than with Coastcross 1 but not dramatically so. Giant progenies cut at 2.5 cm produced 1670 kg/ha more than those cut at 5 cm. The same difference for Coastcross 1 was 1400 kg/ha. In the greenhouse study, both Common giant and Coastcross 1 had higher dry matter yields when cut at the 5 cm height, with Giant showing more sensitivity to severe clippings than Coastcross 1. The response of cultivars to clipping height in field tests was greater with 6-week harvest intervals coupled with higher nitrogen rates. This also was verified by results from individual harvests as shown graphically in Figure 5. Mean yields for the 2.5-cm clipping height were 1257 and 1952 kg/ha above those cut at 5 cm when plants were supplied with 180 and 360 kg/ha, respectively (Table 9).

Bermudagrass cultivars responded similarly to nitrogen and clipping height treatments as indicated by the lack of significant interactions (Figure 5). At the 6-week harvest interval, the relatively higher response shown by Coastcross 1 over Giant hybrids to higher nitrogen application (Table 7) was due to the fact that Giant progenies tended to produce long, thin stems and bear few thin leaves and a greater mass of seed heads. Comparatively, Coastcross 1 produced a

Table 9. Dry matter yields as affected by nitrogen levels, clipping heights, and cultivars in the field study.

Clipping height	Nitrogen Levels 180 kg/ha	360 kg/ha	Mean
	Dry matter yields kg/ha		
2.5 cm	14066*	19298	16682*
5 cm	12809	17346	15078
advantage for 2.5 cm	1257	1952	1684
mean	13438#	18322	15880

* LSD$_{.05}$ for nitrogen level x clipping height means = 760

**LSD$_{.05}$ for clipping height means = 1960

\# LSD$_{.05}$ for nitrogen levels means = 1950

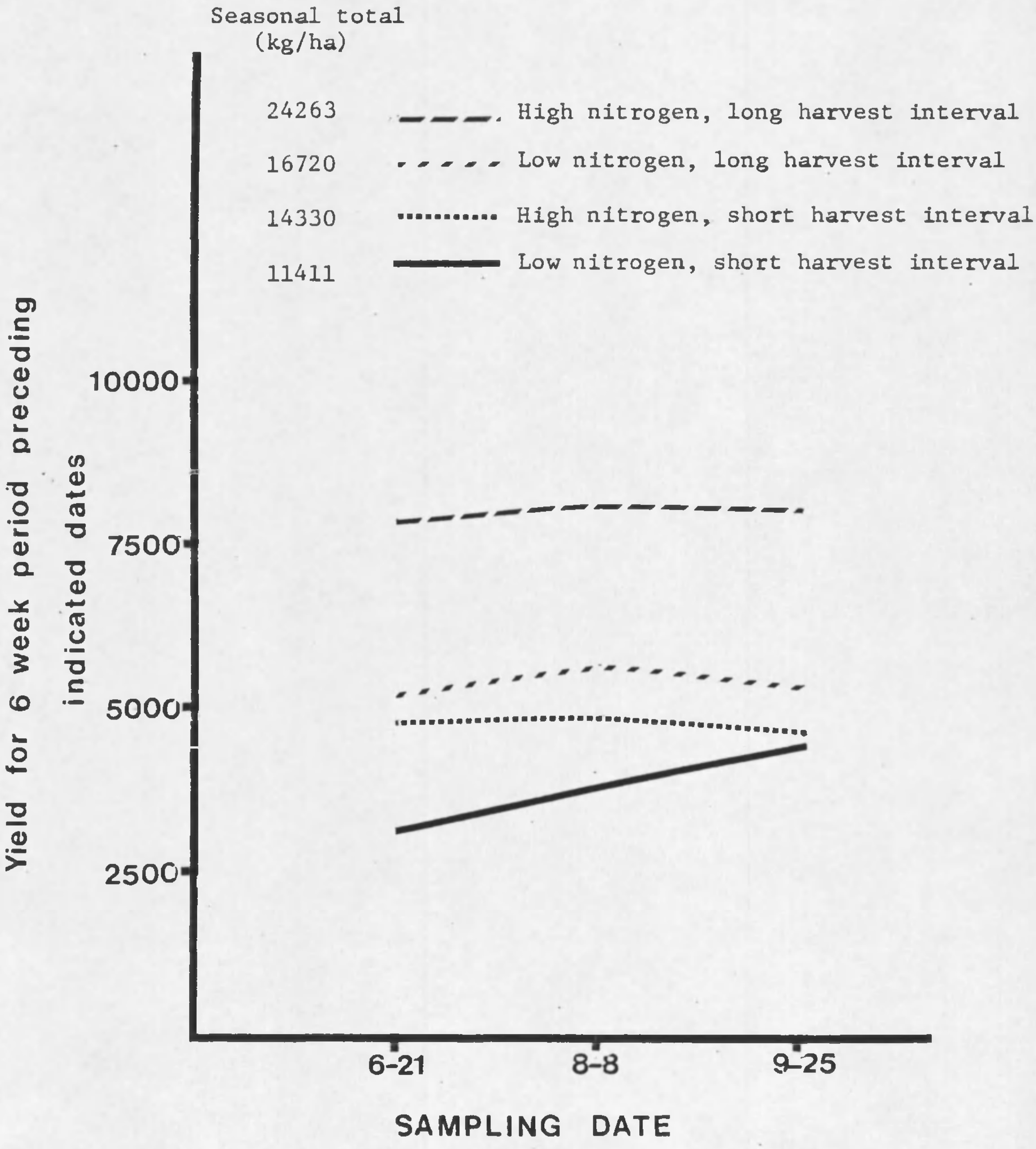

Figure 5. Performance of bermudagrasses in response to nitrogen levels, harvest intervals and close clipping.

large mass of thick stems bearing more and larger leaves with lower seed head frequency (conforming to previous findings by Prine and Burton, 1956; Burton and Devane, 1954; Mathias et al., 1978). Under low nitrogen fertilization and at the 6-week schedules particularly, Coastcross 1 produced less vegetative mass and more dense seed heads at an earlier stage than did the Giant hybrids. This lead to a yield reduction coupled with low forage quality.

The growth of bermudagrass and subsequently dry matter yields of both the Giant hybrids and Coastcross 1 were influenced by low temperatures recorded on May 1981 and at the last period of the experiment, September 1981. Optimum temperature range for bermudagrass growth, as indicated by Beard (1973), ranged from 26 to 35 C. In the field study an analysis of individual harvest data showed that the lowest dry-matter yields were obtained at the first 3-week clipping achieved June 1, 1981 and the last 3-week clipping made September 25, having respectively an average temperature of 23.3 C with a maximum of 32 C and 30 C with a maximum of 38.8 C. Dry matter yields for the first and last 3-week clippings were, respectively 966 and 1467 kg/ha for Coastcross 1 compared with 1058 and 1344 kg/ha for Giant hybrids. Yields for the second 3-week harvests achieved June 21 and having an average temperature of 32 C with a maximum of 40 C were 3377 and 2966 kg/ha for Coastcross 1 and Giants, respectively. At the 6-week cuts, bermudagrass cultivars showed lower dry matter production at the first 6-week sampling achieved June 21. Yields corresponding to the first and second 6-week harvests were, respectively, 6069 and 6829 kg/ha for Coastcross 1 compared with 6352 and 6689 kg/ha for the Giants.

As far as the effect of the treatments mentioned with regard to forage quality, it is evident that long harvest intervals coupled with the higher nitrogen application gave the highest yields in terms of dry matter. In contrast, the younger the forage, the more palatable it was and the higher protein percentage it had. Burton (1954) stated that palatability, protein percentage and digestibility were reduced as the clipping time was delayed. There is, however, more protein produced/ha when the harvest interval is increased because of higher dry matter production. Burton (1954) indicated that Coastal bermudagrass cut at 3- and 6-week intervals had 16.6 and 11.3% crude protein. Using these protein percentages and forage yields in this test for the 6-week harvest intervals and high nitrogen fertilization (Table 7), protein production was higher for the 6-week intervals (2566 vs 2313 kg/ha) than with the 3 week intervals. Burton added that cellulose content of forage cut at the frequency of 3 and 6 weeks was 28.7 and 32%, respectively. This increase of cellulose content in response to long harvest intervals results in reduced quality and subsequently in low forage use efficiency. Productivity of pastures is a function of whether the quantity or the quality of forage produced is the desired objective.

SUMMARY

Species performance and potential are controlled in part by the species genetic make-up and in part by the environmental and management conditions.

In a greenhouse study, Common giant was surpassed by Coastcross 1 for dry matter yields, and the difference between cultivars was significant. In a field test, the Giant hybrids did not show the inferiority expressed by Common giant, but had equivalent yields to those from Coastcross 1 as indicated by the lack of a significant different among cultivars (Table 6). Brown et al. (1976) reported that Coastcross 1 had higher yields than Coastal and Common bermudagrass in Southern Mississippi. Average yields obtained at the Mesa, Arizona Experiment Station for the period 1975-1976 (5 cuts 1975 and 4 cuts 1976, 85 kg N/ha after each cutting) from the bermudagrasses B442 x B445, Coastcross 1, Giant, and Common were 26808, 25960, 23232, and 15042 kg/ha, respectively (Kneebone, unpublished data).

Management factors including fertilization, harvest interval and height have shown significant influence on species performance, leading accordingly to significant variation in the trend of dry matter production and forage quality as well. High nitrogen fertilization contributed to an increase in dry matter production. There was, however, variability among cultivars in response to nitrogen application rates. In the greenhouse, Common giant showed more response/additional kg N than Coastcross 1 as indicated by the yield response (4.4 vs 1.85 kg/kg N). In the field, Coastcross 1 responded more favorably to higher nitrogen rates than Giant hybrids (Table 9).

The influence of harvest interval was marked by an increase in dry matter yields in response to longer intervals. Harvesting at 6-week intervals gave higher dry matter yields than 3- and 4-week cuts as indicated by previous findings as well as results shown by both the greenhouse study and the field test. All bermudagrass cultivars responded favorably and in the same pattern to longer harvest intervals. Very long harvest intervals, however, might contribute to loss of production and forage quality as well.

Clipping height effects showed no consistent trend, since in the greenhouse there was more dry matter produced at the 5-cm cutting height, while in field dry matter yields were higher at close clipping (2.5 cm above ground). Coastcross 1 showed less sensitivity to close clipping than did the giant bermudagrasses in both situations (greenhouse and field).

LITERATURE CITED

Adegbola, A. A. and C. M. McKell. 1966. Regrowth potential of coastal bermudagrass as related to previous Nitrogen fertilization. Agron. J. 58(2): 145-146.

Adegbola, A. A. and C. M. McKell. 1966. Effect of nitrogen fertilization on the carbohydrate content of Coastal bermudagrass (Cynodon dactylon (L.) Pers.). Agron. J. 58(2): 60-65.

Andrews, A. C. and F. C. Crafts. 1979. Hybrid bermudagrass compared with kikuyu and common couch in Coastal New South Wales. 1-Establishment, dry matter production and persistence. Aust. J. Exp. Ag. and Animal Husb. 19(99): 437-443.

Andrews, A. C. and F. C. Crafts. 1979. Hybrid bermudagrass compared with kikuyu and common couch in Coastal New South Wales. 2-Crude protein content and estimated in vivo digestibility. Aust. J. Exp. Ag. and Animal Husb. 19(99): 444-447.

Ashley, D. A., O. L. Bennett, B. D. Doss and C. E. Scarsbrook. 1965. Effect of nitrogen rate and irrigation on yield and residual N recovery by warm season grasses. Agron. J. 57(4): 370-372.

Barrios, E. P., L. G. Jones and K. Koonce. 1979. The relationship between some nitrogen fertilizer sources, rates, application frequencies, and quality of 'Tifgreen' bermudagrass. J. Am. Soc. Hort. Sci. 104(1): 84-88.

Barton, B. S. and G. A. Jung. 1968. Effect of environmental conditions on the growth of four perennial grasses. Agron. J. 60(2): 155-162.

Beard, J. B. 1973. Temperature. (in) Turfgrass Science and Culture (Prentice-Hall, Inc. N.J.) pp: 209.

Beaty, E. R., K. H. Tan, R. A. McCreery and J. D. Powell. 1980. Yield and nitrogen content of closely clipped bahiagrass as affected by N treatments. Agron. J. 72(1): 56-60.

Blaser, R. E. 1946. The effect of cutting methods and sod treatments on the yield and protein content of carpetgrass, Axonopus affinus Chase. J. Am. Soc. Agr. 38(5): 394-397.

Brown, W. E., J. M. Spiers and C. W. Thurman. 1976. Performance of 5 warm-season perennial grasses grown in Southern Mississippi. Agron. J. 68(5): 821-823.

Burton, G. W. 1947. Breeding bermudagrass for the south eastern United States. J. Am. Soc. Ag. 39(7): 551-569.

Burton, G. W. 1954. Coastal bermudagrass for pasture, hay and silage. Geo. Ag. Exp. Sta. Bul. ns2.

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. Agron. J. 44(3): 128-132.

Burton, G. W., J. E. Jackson and R. H. Hart. 1963. Effects of cutting frequency and nitrogen on yield, in vitro digestibility, and protein, fiber, and carotene content of Coastal Bermudagrass. Agron. J. 55(5): 500-502.

Burton, G. W., B. L. Southwell and J. C. Johnson Jr. 1956. The palatability of Coastal bermudagrass (Cynodon dactylon (L.) Pers.), as affected by nitrogen level and age. Agron. J. 48(8): 360-362.

Burton, G. W. and W. G. Monson. 1978. Registration of Tifton 44 bermudagrass (Reg. No. 10). Crop Sci. 18: 911.

Carocostas, R. and J. Vicente-Chandler. 1981. Effect of three grazing intervals on carrying capacity and weight gains produced by stargrass pastures. J. of Ag. of the Univ. of Puerto-Rico, V. LXV (1).

Chiles, R. E., W. Huffine and J. Q. Lynd. 1966. Differential response of Cynodon varieties to type of sprig storage and planting depth. Agron. J. 58(2): 231-233.

Coats, R. E. 1957. Coastal bermudagrass in Mississippi. Mississippi Ag. Exp. Sta. Bul. 549.

Cooper, B. R. and G. W. Burton. 1965. Forage and turf potential of giant bermudagrass in the Southeastern United States. Agron. J. 57(3): 239-240.

Day, B. E. and L. S. Jordan. 1961. Spray retention by bermudagrass. Weeds 9(3): 351-355.

Decker, A. M., R. W. Hemkin, J. R. Miller, N. A. Clark and A. V. Okarie. 1971. Nitrogen fertilization, harvest management, and utilization of "Midland" bermudagrass (Cynodon dactylon (L.) Pers.). Maryland Ag. Exp. Sta. Bul. 487.

Dittmer, J. H. 1973. Clipping effects on bermudagrass biomass. Ecology. 54(1): 217-219.

Doss, B. D., D. A. Ashley, O. L. Bennet and R. M. Patterson. 1966. Interactions of soil moisture, nitrogen, and clipping frequency on yield and nitrogen content of Coastal bermudagrass. Agron. J. 58(5): 510-512.

Faix, J. J., C. J. Kaiser and F. C. Hinds. 1981. Bermudagrass for forage in the central U.S. transitional climatic zone. Agron. J. 73(3): 313-316.

Graber, L. F. 1931. Food reserves in relation to other factors limiting the growth of grasses. Plant Physiology. 6(1): 43-71.

Griffith, W. K. and M. R. Teel. 1965. Effect of nitrogen and potassium fertilization, stubble height and clipping frequency on yield and persistence of orchardgrass. Agron. J. 57(2): 147-149.

Hallock, D. L., R. H. Brown and R. E. Blaser. 1965. Relative yield and composition of Ky. 31 fescue and Coastal bermudagrass at four nitrogen levels. Agron. J. 57(6): 539-542.

Hanna, W. W. and G. W. Burton. 1977. Cytological and fertility characteristics of some hybrid bermudagrass cultivars. Crop Science. 17 (2): 243-245.

Harlan, J. R., J. M. J. deWet, W. Huffine and J. R. Deakin. 1970. A guide to the species of Cynodon (Gramineae). Oklahoma State Univ. Exp. Sta. Bull. B-673.

Harrison, C. M. 1931. Effect of cutting and fertilizer application on grass development. Plant Physiology. 6: 669-684.

Hojjati, S. M., R. A. McCreery and W. E. Adams. 1968. Effects of nitrogen and potassium fertilization, irrigation, and clipping interval on chemical composition of Coastal bermudagrass (Cynodon dactylon (L.) Pers.) I-Total available carbohydrates. Agron. J. 60(6): 617-618.

Holt, E. C., R. C. Potts and J. F. Fudge. 1951. Bermudagrass research in Texas. Texas Ag. Exp. Sta. Circular 129.

Holt, E. C., J. C. Read, B. E. Conrad and W. C. Ellis. 1979. Performance of Tifton 44, callie, and experimental hybrid bermudagrasses. Texas Ag. Exp. Sta. PR. 3588.

Jung, G. A., J. A. Balasko, F. L. Alt and L. P. Stevens. 1974. Persistence and yield of 10 grasses in response to clipping frequency and applied nitrogen in the Allegheny Highlands. Agron. J. 66(4): 517-521.

Kneebone, W. R. 1972. Breeding seeded varieties of bermudagrass for turfgrass use. Proc. Scotts, Turfgrass Res. Conf. 4: 144.

Kunelius, H. T. 1979. Effects of harvest schedules and nitrogen fertilization on yields, quality, and ground cover of bromegrass. Canad. J. Plant Sci. 59(1): 257-259.

Mathias, E. L., O. L. Bennett and P. E. Lundberg. 1978. Fertilization effects on yield and N concentration of Midland bermudagrass. Agron. J. 70(6): 973-976.

McCreery, R. A., S. M. Hojjati and E. R. Beaty. 1966. Nitrates in annual forages as influenced by frequency and height of clipping. Agron. J. 58(4): 381-382.

Morris, H. D. and J. F. Celecia. 1962. Effect of time of fertilizer application on yield and nutrient uptake of Coastal bermudagrass on Cecil sandy loam. Agron. J. 54(4): 335-338.

Nelson, B. D., C. R. Montgomery, E. B. Morgan, D. M. Johns and H. D. Ellzey. 1980. Effects of harvest date and age on quality of Coastal bermudagrass. Louisiana Ag. Exp. Sta. Bull. No. 730.

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 (L.) Pers.). Agron. J. 48(7): 296-301.

Rathore, D. N. and K. Vijay. 1977. Forage potentials of dinanathgrass and sorghum as influenced by nitrogen and phosphorus fertilization. Ind. J. Ag. Sci. 44(3): 153-156.

Reichman, G. A. and D. L. Grunes. 1966. Effects of water regime and fertilization on barley growth, water use, and N and P uptake. Agron. J. 58: 513-517.

Rousse, R. D. 1968. Soil test theory and calibration for cotton, corn, soybeans, and Coastal bermudagrass. Ala. Ag. Exp. Sta. Bul. 375.

Sell, O. E. 1944. Pasture management in Southern States. Nitrogen fertilization of bermudagrass pastures. J. Am. Soc. Ag. 36: 992.

Stanley, R. L., E. R. Beaty and J. D. Powell. 1967. Effect of clipping height on forage distribution and regrowth of Pensacola bahiagrass. Agron. J. 59(2): 185-186.

Stanley, R. L., E. R. Beaty and J. Powell. 1968. Effect of height of cut on yield of Pensacola bahiagrass. Agron. J. 60(4): 356-358.

Stephens, J. L. 1952. Bermudagrass pastures of the Coastal plains of Georgia. Ga. Coastal Plain Exp. Sta. Bul. 27: 7.

Sturkie, D. G. and R. D. Rousse. 1968. P and K on Zoysia and Tiflawn bermudagrass. Ala. Ag. Exp. Sta. Bul. 383.

Taliaferro, C. M. 1974. Bermudagrass strain evaluation test. Okl. Ag. Exp. Res. Rep. P. 701, P. 705.

Taliaferro, C. M. and J. P. Alexander. 1974. Bermudagrass strain tests. Okl. Ag. Exp. Sta. Res. Rep. P. 698.

Taliaferro, C. M. and J. P. Alexander. 1977. Bermudagrass strain tests. Okl. Ag. Exp. Sta. Res. Rep. P 753.

Taliaferro, C. M. and W. L. Richardson. 1976. Bermudagrass varieties. Okl. Ag. Exp. Sta. Res. Rep. P. 738.

Taliaferro, C. M. and W. L. Richardson. 1976. Bermudagrass evaluation test. Okl. Ag. Exp. Sta. Res. Rep. P. 740.

Thomas, J. R. and G. W. Langdale. 1980. Ionic balance in Coastal bermudagrass influenced by nitrogen fertilization and soil salinity. Agron. J. 72(3): 449-452.

Thompson, Lyell. 1977. Effect of fertilizers and limestone on yield and winter kill of Coastal bermudagrass. Arkansas Farm Research 26(5): 7-8.

Utley, P. R., R. S. Lowrey, W. H. Marchant, R. E. Hellwig, J. L. Butler, and W. C. McCormick. 1971. Comparative feeding value of pelleted Pensacola bahiagrass and Coastcross 1 bermudagrass harvested at 4 and 8 weeks of age. J. Anim. Sci. 33(1): 147-150.

Watkins, J. M. 1940. The growth habits and chemical composition of bromegrass (_Bromus inermis_, Leyss) as affected by different environmental conditions. J. Am. Soc. Ag. 32(7): 527-538.

Watkins, J. M. and M. Lewy-Van Severen. 1957. Effect of frequency and height of cutting on the yield, stand, and protein content of some forages in El Salvador. Agron. J. 43(6): 291-296.

Wilkinson, S. R., L. F. Welch, G. A. Hillsman and W. A. Jackson. 1968. Compatibility of tall fescue and Coastal bermudagrass as affected by nitrogen fertilization and height of clip. Agron. J. 60(4): 359-362.

Wilsie, C. P., E. K. Akamine and M. Takahashi. 1940. Effect of frequency of cutting on the growth, yield, and composition of napier grass (_Pennisetum purpureum_ Schum). J. Am. Soc. Ag. 32(4): 266-273.

Wright, N. 1962. Effects of management practices on forage yield and percent protein in blue panicgrass (_Panicum antidotale_ Retz.) Agron. J. 54(5): 413-416.

Wright, M. J., G. A. Jung, C. S. Brown, A. M. Decker, K. E. Varney and R. C. Wakefield. 1967. Management and productivity of perennial grasses in the North-East. II-Smooth bromegrass. W. Va. Ag. Exp. Sta. Bul. 544T. III-Orchardgrass W. Va. Ag. Exp. Sta. Bul. 557T.