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Comparing bermudagrass and bahiagrass cultivars at different stages of harvest for dry matter yield and nutrient content

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COMPARING BERMUDAGRASS AND BAHIAGRASS CULTIVARS AT DIFFERENT STAGES OF HARVEST FOR DRY MATTER YIELD AND NUTRIENT CONTENT

A Thesis

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
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requirements for the degree of
Master of Science

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by
Ryan Thomas Dore'
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Abstract

Rapid growth of warm-season grasses such as bermudagrass (*Cynodon dactylon*) and bahiagrass (*Paspalum notatum*) is associated with a decline in their nutritional value. This study was initiated to provide production and composition data with different cultivars of bermudagrass (common, Russell, Jiggs) and bahiagrass (Tifton-9, Pensacola, Argentina). Dry matter (DM), ash, crude protein (CP), neutral detergent fiber (NDF), and acid detergent fiber (ADF) composition and production were evaluated every two weeks for a ten-week period on six different cultivars. Also, Russell bermudagrass was evaluated in a second trial very similar to the first trial for composition and production but was started at three different harvest times. Bermudagrass cultivars had higher DM ($P < 0.05$) than bahiagrass at all stages of maturity except for d 14. Dry matter production was less than 2000 kg/ha at the 14-d harvest for all of the cultivars. Jiggs produced more DM ($P < 0.05$) than the other grasses at 42-d harvest. Ash (%) decreased at a constant rate from day 14 until day 70. There was no significant difference ($P > 0.05$) among the three bermudagrasses and Argentina bahiagrass CP (%) at the 14-d harvest. Russell produced the least amount ($P < 0.05$) of CP at d 14, while Argentina produced the most CP. Russell, common, and Pensacola CP production (kg/ha) were similar ($P > 0.05$) and each were higher than Tifton-9 and Argentina after 42 days of growth. Bahiagrass NDF (%) was similar ($P > 0.05$) across the three cultivars at each of the different harvest times except for the 42-day harvest where Argentina had higher NDF levels ($P < 0.05$) than either Tifton-9 or Pensacola. The bahiagrass cultivars were similar ($P > 0.05$) in NDF production at 42 days. Jiggs produced more ($P < 0.05$) NDF than the other grasses at 56 and 70-d of growth. Common had the least amount of ADF at 56 and 70-d harvest ($P < 0.05$). ADF production was the highest ($P < 0.05$) in Jiggs from d 28 to d 70 of growth. Russell early- and mid-season harvest had greater

(P < 0.05) DM (%) and production than in the late season. Crude protein was the highest (P < 0.05) in both the early and mid season harvested Russell. The late season harvested Russell produced the least amount (P < 0.05) of DM and the least amount (P < 0.05) of CP. It was predicted that the late season harvested Russell would maintain DM and CP production at a constant rate for a longer period of time. This means that it would allow a producer a wider range of time to make hay or even graze this forage at that time of the year.

Chapter I

Introduction

Cow-calf operations dominate Louisiana's cattle industry. These operations are predominantly forage-based systems. The hot, humid summer days with adequate rainfall allow cattle producers to grow large amounts of warm-season forages such as bermudagrass (*Cynodon dactylon)* and bahiagrass (*Paspalum notatum*). These forages are C_4 grasses that are more metabolically efficient than temperate forages (C_3). C_3 plants fix energy into 3-carbon units and C_4 plants fix energy into 4-carbon units (Ball et al., 1996). Peak forage DM production occurs in midsummer, however, animal production is often depressed, due to decreased forage quality (Sollenberger et al., 1989; Sollenberger and Jones, 1989; Rusland et al., 1988).

Beef producers face the problem of maintaining forage quality in an environment where forage production can change rapidly depending on several environmental factors. At times, when environmental conditions are favorable, harvesting (grazing or mechanical) within a timely manner can be very difficult. In times of drought, producing adequate levels of forages are difficult. Moving from medium quality to low quality can occur within a two to four wk period under certain conditions, making managing forage quality very difficult.

In Louisiana, both cool-season and warm-season grasses often contribute to the forage supply. Warm-season grasses produce much edible dry matter, but generally they are of lower digestibility (Reid et al., 1988). In contrast, most cool-season grasses used in the state provide adequate nutrition even at a mature state. Warm- and cool-season grasses differ considerably in chemical and physical characteristics that can affect feed intake and digestion (Akin, 1986; Reid et al., 1988).

The first study was initiated to provide composition and production data among different cultivars of bermudagrass (common, Russell, Jiggs) and bahiagrass (Tifton 9, Pensacola, Argentina) at different stages of maturity grown under similar environmental conditions. The second study was initiated to compare season of harvest within harvest time of Russell bermudagrass.

Chapter II

Review of Literature

Introduction

Warm-season grasses produce much edible dry matter, but are typically low in digestibility (Reid et al., 1988). Warm- and cool-season grasses differ considerably in chemical and physical characteristics that can affect feed intake and digestion (Akin, 1986; Reid et al., 1988). Warm-season grasses are generally lower in forage quality (crude protein (CP) and digestibility) at a given stage of maturity than temperate grasses due to a relatively low leaf-to-stem ratio and chemical and physical characteristics associated with the C4 plants (Jones, 1985). Warm-season grasses also have rapid rates of maturation. Forage dry matter (DM) production of these grasses often peaks in mid-summer, however it is possible for animal performance (weight gains) to be depressed. This depression is related to decreased forage quality (Sollenberger et al., 1988).

The predominant warm-season pasture grasses in Louisiana are bermudagrass (BEG) (*Cynodon dactylon*) and bahiagrass (BAG) (*Paspalum notatum*). Both bermudagrass and bahiagrass can tolerate a wide range of soil conditions and are commonly used for grazing and/or hay production.

Bahiagrass is a warm-season perennial bunch grass native to South America. The Florida Agricultural Experiment Station first introduced common BAG to the US in 1913. Bahiagrass has several characteristics that make it valuable as a pasture grass. Bahiagrass grows on a wider range of soils than does bermudagrass. It usually will green up earlier and remain green longer in the fall than bermudagrass. A negative role of bahiagrass is that it lacks the drought tolerance of bermudagrass on deep sandy soils. It is recommended that bahiagrass should primarily be used for pasture, although some is harvested and conserved as hay (Redmon, 2000).

Bermudagrass has been part of southern agriculture for at least 250 years. Hybrid bermudagrass with improved productive capability and nutritive value has played an important role in livestock production across the southern US for nearly 60 years with the introduction of 'Coastal' in 1943 by Dr. Glen Burton, USDA-ARS, Georgia Coastal Plains Experiment Station at Tifton, GA. Bermudagrass is a warm-season perennial that spreads mainly by rhizomes (underground stems) and stolons (horizontal aboveground stems). The grass tolerates a wide range of soil types and soil pH values, thus making it adapted to most of the southern US. Besides providing nutrition for cows during the growing season, bermudagrass also is harvested and conserved extensively as hay for livestock winter-feeding programs (Redmon, 2000).

Plant Structure

Plants derive energy from the sun, fixing carbon into their cellular structures. Distribution of this carbon and energy within a plant is greatly affected by environmental factors and the species of plant, thus forage quality is a combination of the environment and the genetic factors of the plant (Van Soest, 1982).

There are two major functions of plant survival relevant to the nutritive quality of forage: storage of nutrients and defense against the environment. Plant reserves are needed for survival during periods of cold or drought and to provide nutrients for regrowth following defoliation, grazing, or cutting. These reserves are usually located in the highly digestible segments of the plant (cell soluble). Other structures such as lignin, cutin and secondary compounds are highly resistant to degradation and are usually associated with plant support and defense (cell walls). These structures by design are lower in digestibility and thus reduce the nutritive value of the forage. Thus, forage quality is primarily determined by its composition, or ratio of digestible and indigestible components. Consequently, a sequence of cause-effect relationships exist among the environment and plant species (Van Soest, 1982).

From an analytical standpoint, forages can be divided into 2 main components, the cell solubles and the cell walls. The cell solubles contain the portion of the plant that involves metabolism and growth of the plant. In contrast, the cell walls contain the portion of the plant that provides structure and protection (Van Soest, 1982).

Ruminant animals have the ability to utilize vegetative plant material as their only source of nutrients (Hofmann, 1989). Unlike seeds, vegetative tissues contain a large percentage of their organic matter in the cell walls that provide structural integrity to the plant. The rumen allows for utilization of forages through a symbiotic relationship with microorganisms able to ferment the polysaccharides in plant cell walls and that are not amenable to mammalian enzymatic hydrolysis (Hungate, 1966). In other words, without the rumen and the relationship with the microorganisms that it houses, cattle would not utilize cellulose or hemicellulose in plants any better than humans.

Fractionation of the carbohydrate component of forages is based on the system developed by Van Soest et al. (1991). The basis for this system is to break the carbohydrate components into fiber components (cell walls) and soluble components (cell solubles). The first step in this is conducting a NDF (neutral detergent fiber) analysis. This procedure refluxes the forage sample in neutral (pH = 7) detergent solution for 1 hour, which removes the solubles and leaves the fiber components. The primary components of the residue are hemi-cellulose, cellulose, and lignin. The next step is to reflux the sample in an acid (pH = 4.5) detergent solution. This procedure removes the hemi-cellulose fraction, leaving primarily cellulose and lignin in the residue.

The cell-wall fraction of plants has been implicated as a control mechanism for forage intake by ruminants (Waldo, 1986). A reduction in the concentration of cell-wall material may improve both intake and energy density of forages. Increased digestibility of the cell wall would improve energy availability. The plant cell wall is a complex biological structure containing many different molecules whose biosynthesis is controlled by enzymes encoded and regulated by genes (Iiyama et al., 1993). The different methods of fiber analysis are analytical product which describe those forage components that have low solubility in specific solvent systems and less digestible than starch. In some cases, such as mature grasses, the cell wall and fiber concentrations of forages are very similar, whereas for legumes the fiber estimates are routinely lower than the cell-wall concentration (Theander and Aman, 1980).

Although all plant cell walls have a similar basic architecture, there are important differences among the major taxonomic groups of forages in details of wall composition and structure. Legume leaves contain much less cell wall than do leaves of grasses, and legume leaves do not exhibit the increase in cell-wall concentration associated with maturation of the plants that occurs in grass leaves (Wilman et al., 1977; Wilman and Altimimi, 1984). Stem material of all forages is higher in cell-wall concentration than their leaves, and stems always increase in wall content with maturity (Griffin and Jung, 1983; Albrecht et al., 1987; Jung and Vogel, 1992). Lignin is the major component of the cell wall that is recognized as limiting digestion of the cell wall polysaccharides in the rumen. Lignin seems to exert its negative effect on cell-wall polysaccharide digestibility by shielding the polysaccharides from enzymatic hydrolysis (Jung and Deetz, 1993). Lignin’s influence of fiber digestibility has been shown to be greater in grasses than in legumes (Smith et al., 1972; Buxton and Russell, 1988).

Forage Maturity

Forage yield and nutritional qualities of pasture are influenced by numerous factors representing ecological conditions and management activities. Those factors include frequency of cutting, species composition, plant maturity, climatic conditions, soil fertility status, and harvest season (Van Soest, 1982). The two most influential factors that affect forage quality and forage utilization are forage species and forage maturity. According to Van Soest (1982) as a pasture matures, fiber and lignin contents are high while protein content is low. When comparing temperate grasses to tropical grasses, tropical forages usually have increased annual dry matter yields. Changes of quality during the growing period of grasses are particularly high under tropical climatic conditions (Nelson and Moser, 1994).

The maturity of forages plays a key role in the clearance of rumen material. Clearance of digesta from the rumen is the primary process that affects forage intake by ruminants (Ulyatt et al., 1986). This process depends largely on digestion by ruminal microorganisms and on rate and extent of particle size reduction (Moseley, 1982). According to Moseley (1982), any type of forage particle must be reduced to a specific size before it can exit the rumen.

Age and Maturity

Forage quality can be described by a plants development due to its stage of growth. Plant maturity is defined as the morphological development culminating in the appearance of the reproductive cycle: tillering, flowering, pollination, and seed formation. Plant age is generally defined as the period since the beginning of regrowth in spring following winter, or growth of aftermath following the time of cutting or grazing. Some factors that may accelerate the maturation process are high temperature, longer periods of light, water, and soil fertility; those that retard it are clipping, grazing, disease, drought, lower temperature, less periods of light and soil fertility (Van Soest, 1982).

Forage age greatly influences physiological plant maturity; however, the relationship can be greatly modified by individual plant responses and environmental factors. Johnson et al. (2001) observed that forage mass had a quadratic relationship with harvest date, with peak forage mass occurring in late June and July. Sumner et al. (1991) compared year-round bahiagrass yield on nine south Florida ranches and reported that peak yields occurred during midsummer (late July). Additionally, Chambliss et al. (1999) and Mislevy (1999) reported that peak mass for bermudagrass and stargrass occurred during midsummer (late July).

Age and maturity of plants affect the intake level as well as animal performance. Phillips et al (2002) reported that 82% kenaf hay pellets harvested 58 days post planting were successfully used to replace alfalfa pellets without decreasing intake, N balance, or performance of crossbred wethers less than 1-yr old and weighing 36.4 kg. Rinne et al. (2002) reported that increased maturity reduced silage and total DM intake and milk yield, while effects on milk composition were minor. Earlier harvest of grass lowered ruminal fluid pH and increased VFA and ammonia concentrations. The proportion of butyrate to other VFA decreased with advancing maturity, but effects on propionate proportions were less consistent. Ruminal fluid protozoa decreased with advancing maturity of grass silage (Rinne et al., 2002).

Summer grasses can be left alone and not harvested for hay production in the late summer or early fall. This is considered to be stockpiled forage. A trial was conducted in Overton, Texas where six seeded bermudagrass cultivars, two bahiagrass cultivars, and a kikuyugrass cultivar were compared with ‘Coastal’ and ‘Tifton 85’ bermudagrass in a small plot study. The trial was looking at these grasses as a potential for grazing stockpiled forage after the first frost. Evers et al. (2004) reported that Tifton 85 had greater autumn standing forage mass than bahiagrass and kikuyugrass. Crude protein concentrations declined slowly from October to February and were always above the minimum requirements for a nonlactating pregnant cow. Acid detergent concentrations among the bermudagrass, bahiagrass, and kikuyugrass increased with time. Bahiagrass cultivars always had some of the highest ADF concentrations, which suggest they may not be the best warm-season perennial grass for stockpiling (Evers et al., 2004).

Leaf and Stem

Forage maturity is frequently associated with less leafiness and an increasing stem-to-leaf ratio. Stems are usually associated with lower-quality components than the leaves on forages; however, this is not always true. Alfalfa and many other legumes species use the stem as structural components (lower-quality) and the leaves as metabolic organs (higher-quality). In contrast, grasses use leaves for both structure through the lignified midrib and as metabolic organs. Thus, the nutritive value of alfalfa leaves will be maintained during the aging process where as grass leaves will decrease in quality (Van Soest, 1982).

However, in some grasses, the stem is considered to be a reserve organ and this will lead to the stems having a higher quality than the leaves. For example, timothy and sugarcane utilize the stem as a reserve organ (Van Soest, 1982). Newman et al. (2002) showed that canopy height of continuously stocked limpograss pastures affects herbage N fractionation and degradation parameters. The lag time for CP degradation from all canopy heights was much longer than reported for temperate forages and somewhat longer than other C4 grasses.

Date of Cutting

The date for obtaining an optimum (economically and financially feasible) yield of digestible matter varies and is relatively later in the northern US compared to the southern US and is later in regions of higher elevation. Higher environmental temperature encourages lignification and more rapid physiological development so the forage will become less nutritive. Thus, first harvest of forages is generally higher in quality due to lower temperatures. The second cuttings are usually lower in digestibility than the first cuttings of the same chronological and physiological ages (Van Soest, 1982).

Flores et al. (1993) reported that Pensacola bahiagrass had only 48% leaf blade when determining total forage DM for June harvested grass when compared to 89% leaf blade in Mott elephant grass. The remainder of the June harvested Pensacola grass was mainly seed stalks (peduncle plus inflorescence). Interactions and inconsistencies among grasses and seasons existed. For example, June-harvested Pensacola had less digestibility but approximately 6% higher NDF intake than September-harvested Pensacola. Apparently, greater lignin concentration in seed stalks of June-harvested Pensacola decreased in vivo digestibility but did not decrease small-particle passage or voluntary intake.

Johnson et al. (2001) studied NDF concentrations in several species over the growing season. They found a linear increase for NDF concentration in bahiagrass across the harvest season. In contrast, peak levels of NDF in bermudagrass occurred after late June well before harvest. They also found a cubic response for NDF in stargrass with peak levels being observed in late June and September. Mandebvu et al. (1996) observed an inverse relationship between lignin concentration and in-vitro dry matter digestibility (IVDMD) for Tifton 85 bermudagrass.

The 7-wk Tifton 85 forage had lower IVDMD than the 3½-wk grass due to greater maturity. The chemical composition of kenaf hay is greatly influenced by harvesting date. Philips et al. (2002) evaluated kenaf fed as freshly harvested forage and as silage and reported DM digestibility ranging from 58.9% to 82.4%, depending on the date of harvest. In another experiment, the *in situ* disappearance of OM and N fractions of kenaf harvested at different intervals after planting were evaluated. At 62 days after planting, OM in situ disappearance was 73.7%, and N disappearance was 85.5% (Phillips et al., 1996 and 1999).

Temperature

The temperature during forage growth plays a major role in the nutritive value of the forage. Lower digestibility at higher temperatures is the result of the combination of two main effects. Increased lignification of plant cell wall is an effect of higher environmental temperatures, and enzymatic activities associated with lignin biosynthesis are enhanced by increased temperature. A higher environmental temperature also promotes more rapid metabolic activity, which decreases the pool size of metabolites in the cellular contents. Temperature has its greatest effect on plant development in promoting the accumulation of structural matter. Higher environmental temperatures have little effect on the alfalfa leaf, but the stems will increase in percent lignin and the leaf-to-stem ratio may decrease. In contrast, grasses will decline drastically in nutritive value with increased temperatures since the leaves serve as support as well as metabolic function. Both the leaf and stem quality of grasses decline with increasing temperature, and this effect is more pronounced in tropical grasses (Van Soest, 1982). Leaf quality declines particularly as a result of lignification of the midrib, which contains the major portion of the lignin of grass leaves (Deinum, 1976). In an additional study, Deinum et al. (1968) reported a decline of half a unit of digestibility per degree Celsius increase in temperature when light, age, maturity, and fertilization were controlled. Johnson et al. (2001) reported that in-vitro organic matter digestibility (IVOMD) was highest in early June for bermudagrass, bahiagrass, and stargrass than any other harvest time. A midsummer reduction of approximately 10.3% in IVOMD was observed during July when each of these grasses were less than in early June. In August, IVOMD improved for all three forages due to the fact that autumn was approaching. Rusland et al. (1988) found a similar digestibility pattern in limpograss (*Hemarthria altissma*). Sollenberger et al. (1989) reported that the greatest forage digestibility of limpograss and Pensacola bahiagrass occurred with either spring or autumn growth and that IVOMD of bahiagrass was typically reduced during the summer. A decrease in digestibility of 7.6% for bermudagrass and 12.9% for bahiagrass has been reported when temperatures increased from 26 to 35˚C (Henderson and Robinson, 1982). The negative relationship between digestibility and temperature may be caused by a reduction in the leaf-to-stem ratio and increased proportion of the indigestible fractions. This is due to increased metabolic rates of the plant associated with increased temperatures (Nelson and Volenec, 1995; Henderson and Robinson, 1982). Henderson and Robinson (1982) reported a positive relationship between NDF and temperature for bermudagrass, while also reporting a negative relationship in bahiagrass between NDF and temperature. This was due to the leaf-to-stem ratio that bermudagrass contains versus bahiagrass. Increased ADF concentrations for bermudagrass and bahiagrass were positively correlated with higher temperatures (Henderson and Robinson, 1982).

Chapter III

Materials and Methods

A trial was conducted to evaluate the effect of growing time on forage production and forage quality with three cultivars of both bermudagrass (BEG) and bahiagrass (BAG). Bermudagrass cultivars evaluated were Russell, Jiggs, and common. Bahiagrass cultivars evaluated were Argentina, Pensacola, and Tifton 9. A second trial was conducted to evaluate the effects of harvest time within the season on forage production and forage quality with Russell bermudagrass.

Growing Time

Forages (common, Russell, Jiggs, Tifton-9, Pensacola, and Argentina) were established at the Rosepine Research Station in the summer of 1999. Common bermudagrass and the three bahiagrass varieties (Tifton-9, Pensacola, and Argentina) were planted on a prepared seedbed with pure live seed. Common bermudagrass seed was broadcasted at 5.6 kg/ha. Bahiagrass varieties were broadcasted at a seed rate of 16.8 kg/ha. Russell and Jiggs bermudagrass were vegetatively propagated on a prepared seedbed. Soil type was Ruston fine sandy loam. On June 21, 2001, all the plots were cut with a disc mower, the forage removed and 112 kg/ha of N, 44.8 kg/ha of P_2O_5, and 134.4 kg/ha of K_2O was applied per hectare. The fertilizer was a complete mixture of dry fertilizer and was applied with a Gandy dribble box applicator. Subsequently, the plot area was clipped the same day with a lawn mower to a stubble height of 2.54 cm.

Each of the 6 cultivars was divided into 30 plots of approximately 1.83 m by 6.1 m. Five harvests were made at 2 wk intervals beginning July 5, 2001. On harvest day, 6 plots of each cultivar were harvested. A 1.22 m by 6.1 m strip (7.44 sq meters) was harvested down the center using an Almaco sicklebar harvester. The forage was clipped to a 5 cm stubble height. The forage from each subplot was weighed and served as the harvested plot weight. A random sample was taken from the harvested material. The sample was weighed (averaged approximately .91 kg) and dried at 70°C for 120 hrs. Dried samples were then ground through a Wiley mill with a 1 mm screen for laboratory analysis. Plot dry matter yields were calculated for each subplot based on the dry matter factor determined from drying each random sample.

Harvest Time

Three replications of 30 plots of Russell bermudagrass were assigned to be harvested at two wk intervals, but each set of plots had a different start date. One was identical to those used in the cutting time trial. Start dates for the other two sets of plots were July 19, 2001and August 16, 2001. Plot management and sample collection procedures were the same as in the cutting time trial.

Chemical Analyses

Samples were analyzed for dry matter by drying in a forced air oven (110°C) for 24 hrs (AOAC, 1990). Subsequently, the sample was ashed with a muffle furnace (600°C) for at least 2 hrs (AOAC, 1990). Crude Protein (CP) was obtained using Kjeldahl-N procedures (AOAC, 1990). Samples were digested for 2 hrs on a block digestor at 385°C, cooled under a fume hood, distilled with a 2200 Kjeltec Auto Distillation unit and then titrated for NH_3. Samples (0.5g) were analyzed sequentially for neutral detergent fiber (NDF) and acid detergent fiber (ADF) using the procedure described by Van Soest et al., (1991), except that the ANKOM fiber analyzer with filter bags was used.

Data Calculations and Statistical Analysis

Plot production data is presented as kg/ha and is based on the fresh weight of each plot times the dry matter factor obtained by drying a sample of the plot harvest at 70°C for 120 hrs and converting to a kg/ha basis. The conversion from lbs/ac to kg/ha was obtained by dividing the lbs. of forage by 2.205 and then multiplying by 2.47. In both trials, data were initially analyzed using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC) in a split plot design. The model compared forages within time. Forage type was the main plot and harvest date (interval) was the sub-plot. Interactions among forage species and growing time were present ($P < 0.05$) for most variables, thus data were subsequently analyzed within growing time as a one-way analysis of variance. The design of the second study was a 3 by 5 factorial with start date and growing time as the main effects. Means were separated using lsd procedures. Data were also analyzed by time within forage cultivar (SAS, 2002). Orthogonal contrast for linear, quadratic, and cubic effects were used to evaluate the effect of growing time within forage type. The REG procedure of SAS was used to develop prediction lines (SAS, 2002).

Chapter IV

Results and Discussion

Forage X Harvest Time

Dry Matter Composition and Production

Bahiagrass DM composition (%) was similar ($P > 0.05$) across the three cultivars at each of the different harvest times except that Argentina had a lower DM content when harvested at 56 days then the other two cultivars (Table 1). Bermudagrass cultivars were more variable, and had higher DM ($P < 0.05$) than Bahiagrass at all harvest times except for 14-d.

Dry matter production was less than 2000 kg/ha at the 14-d harvest (Table 2) for all of the cultivars and would probably not be economical for commercial harvest at this time. Argentina bahiagrass produced ($P < 0.05$) the most DM at the 14-d harvest, followed by Jiggs bermudagrass and Pensacola bahiagrass. There was no difference between ($P > 0.05$) Pensacola and Tifton 9 bahiagrass, although DM production by Jiggs was higher ($P < 0.05$) than Tifton 9. Common bermudagrass produced more DM ($P < 0.05$) than Russell but less than the other forages.

At the 28-d harvest, Jiggs bermudagrass and Argentina bahiagrass produced more DM ($P < 0.05$) than the other grasses (Table 2). There was no difference ($P > 0.05$) in the amount of DM produced among the other grasses at the 28-d harvest. Jiggs produced more DM ($P < 0.05$) than the other grasses at the 42-d harvest. There was no difference ($P > 0.05$) in DM produced among the other grasses at this harvest.

Jiggs maintained ($P < 0.05$) its DM production advantage at the 56-d harvest. Dry matter production was similar ($P > 0.05$) among the other grasses except for Pensacola bahiagrass

Table 1. Dry matter (%) of bermudagrass and bahiagrass cultivars harvested after different growth periods.

	Bermudagrass			Bahiagrass				
Days of growth	Russell	Common	Jiggs	Tifton-9	Pensacola	Argentina	SE	Prob
14	28.6^{a}	26.0^{b}	22.4^{c}	26.3^{b}	25.9^{b}	24.9^{b}	0.6	<.0001
28	33.9^{a}	32.7^{a}	33.2^{a}	30.9^{b}	30.7^{b}	29.3^{b}	0.8	<.0001
42	41.2^{a}	41.3^{a}	39.6^{a}	27.6^{b}	28.4^{b}	27.6^{b}	0.7	<.0001
56	50.2^{a}	45.9^{b}	46.9^{b}	32.2^{c}	30.2^{c}	25.3^{d}	0.9	<.0001
70	30.3^{a}	28.4^{b}	28.1^{b}	25.1^{c}	24.8^{c}	24.2^{c}	0.7	<.0001

[abc] Row means with different superscripts are different ($P < 0.05$).

Table 2. Dry matter (kg/ha) of bermudagrass and bahiagrass cultivars harvested after different growth periods.

	Bermudagrass			Bahiagrass				
Days of Growth	Russell	Common	Jiggs	Tifton-9	Pensacola	Argentina	SE	Prob
14	328^{a}	574^{b}	1212^{c}	1019^{d}	1131^{dc}	1715^{e}	75	<.0001
28	5076^{a}	4251^{a}	6720^{b}	4255^{a}	4713^{a}	5949^{b}	344	<.0001
42	6713^{a}	6826^{a}	8629^{b}	6309^{a}	6273^{a}	6750^{a}	312	<.0001
56	8175^{a}	7557^{a}	10690^{b}	7148^{a}	5660^{c}	7416^{a}	479	<.0001
70	7667^{ab}	6600^{a}	8981^{c}	7737^{b}	7512^{ab}	8818^{bc}	455	0.0087

[abc] Row means with different superscripts are different ($P < 0.05$).

which produced less DM ($P < 0.05$) than any other forage. Jiggs bermudagrass produced more DM ($P < 0.05$) than all other grasses except for Argentina bahiagrass at the 70-d harvest. Dry matter production was not different ($P > 0.05$) among the three bahiagrass cultivars. Common bermudagrass produced ($P < 0.05$) less DM than the bahiagrass cultivars, but the level was not different ($P > 0.05$) than DM produced by Russell bermudagrass. There was no difference ($P > 0.05$) in DM produced among Russell bermudagrass and the bahiagrass cultivars.

Contrast analysis of DM production within forage indicated a quadratic function ($P < 0.001$) for all bermudagrass cultivars (Table 3). Prediction lines (Figure 1) indicated a similar growth pattern for both common and Russell bermudagrass, with the production tending to separate after 40 days. The prediction line for Jiggs bermudagrass indicates a higher rate of production throughout the trial. All three cultivars tended to peak in production around 60-d. Hill et al. (1993) reported that a new high-yielding bermudagrass hybrid, Tifton 85, produced

Table 3. P values for model and contrast analysis for DM (kg/ha) of bermudagrass and bahiagrass cultivars.

	Model	Linear	Quad	Cubic
Russell	<.0001	<.0001	<.0001	0.3033
Common	<.0001	<.0001	<.0001	0.6821
Jiggs	<.0001	<.0001	<.0001	0.8729
Tifton 9	<.0001	<.0001	<.0001	0.5357
Pensacola	<.0001	<.0001	<.0001	<.0001
Argentina	<.0001	<.0001	<.0001	<.0001

26% higher DM yield ($P = 0.05$) with 11% higher IVDMD ($P = 0.05$) than Coastal in two 3-yr trials. Tifton 85 and Jiggs bermudagrass are similar in their physical makeup. They both contain larger stems with bigger leaves.

While DM production of Tifton 9 bahiagrass resulted in a quadratic expression ($P < 0.05$), both Pensacola and Argentina bahiagrass had a cubic pattern of growth (Table 3). The prediction line for Tifton 9 (Figure 2) indicates a similar DM production pattern to both common and Russell bermudagrass. In contrast, both Argentina and Pensacola prediction lines indicated a higher rate of DM production during the early portion of the trial, a slower production during the middle of the trial then an increase towards the end. The prediction lines indicate that Argentina would be expected to have the highest level of production in the first 50 days of growth.

Ash Composition and Production

Bahiagrass ash composition was similar ($P > 0.05$) across the three cultivars at each of the different harvest times (Table 4). Jiggs bermudagrass had the highest ash composition ($P < 0.05$) at day 14, while ash composition of common bermudagrass was higher than the bahiagrass cultivars, but not different than Russell bermudagrass. There was no difference ($P > 0.05$) in ash composition among any of the grasses for the rest of the harvest times.

Argentina bahiagrass and Jiggs bermudagrass produced ($P < 0.05$) the most ash at the 14-d harvest (Table 5). There was no difference between ($P > 0.05$) Tifton 9 and Pensacola bahiagrass, but both of these grasses had higher ash production ($P < 0.05$) than either common or Russell bermudagrass. Russell bermudagrass had the lowest ($P < 0.05$) ash production at 14 days of harvest.

Table 4. Ash (%) of bermudagrass and bahiagrass cultivars harvested after different growth periods.

	Bermudagrass			Bahiagrass				
Days of growth	Russell	Common	Jiggs	Tifton-9	Pensacola	Argentina	SE	Prob
14	7.5^{ab}	8.0^{b}	9.4^{c}	6.7^{a}	7.1^{a}	7.4^{a}	0.3	<.0001
28	6.4	6.9	6.4	6.4	6.2	7.1	0.3	.3397
42	5.7	4.8	5.8	5.5	5.0	5.6	0.4	.2594
56	5.0	5.5	5.1	5.4	5.0	5.6	0.2	.2757
70	4.8	4.4	4.5	4.6	5.1	4.9	0.3	.6937

[abc] Row means with different superscripts are different ($P < 0.05$).

Table 5. Ash (kg/ha) of bermudagrass and bahiagrass cultivars harvested after different growth periods.

	Bermudagrass			Bahiagrass				
Days of growth	Russell	Common	Jiggs	Tifton-9	Pensacola	Argentina	SE	Prob
14	25^a	46^b	114^c	70^d	81^d	126^c	6.	<.0001
28	320^a	301^a	430^b	273^a	290^a	425^b	30	.0010
42	382^a	326^a	501^b	352^a	312^a	378^a	32	.0042
56	402^a	421^a	542^b	383^a	286^c	413^a	30	.0001
70	364	288	399	360	383	431	35	.1140

^{abc}Row means with different superscripts are different ($P < 0.05$).

At the 28-d harvest, Jiggs bermudagrass and Argentina bahiagrass produced more ash ($P < 0.05$) than the other cultivars (Table 5). There was no difference ($P > 0.05$) among the other four cultivars at this harvest time. Jiggs bermudagrass continued to produce more ($P < 0.05$) ash than the other grasses at d 42 and d 56. At the 42-d harvest, there was no difference ($P > 0.05$) among the other five grasses. Pensacola bahiagrass produced ($P < 0.05$) the least amount of ash at 56 days. There were no differences ($P > 0.05$) in ash production by Russell or common bermudagrasses, or Tifton 9 and Argentina bahiagrasses during this d 56 harvest. Ash production was not different ($P > 0.05$) among the six cultivars at the d 70 harvest.

Russell bermudagrass resulted in a cubic expression ($P < 0.05$), while both common and Jiggs bermudagrass had a quadratic pattern of growth (Table 6). Russell and common bermudagrass tended to follow the same pattern early in the growing phase (Figure 3). Russell bermudagrass tended to reach its peak in ash production earlier than common. In contrast, Jiggs

Table 6. P values for model and contrast analysis of ash (kg/ha) of bermudagrass and bahiagrass cultivars.

	Model	Linear	Quad	Cubic
Russell	<.0001	<.0001	<.0001	0.0450
Common	<.0001	<.0001	<.0001	0.9871
Jiggs	<.0001	<.0001	<.0001	0.4620
Tifton 9	<.0001	<.0001	0.0002	0.4699
Pensacola	<.0001	<.0001	<0113	0.0011
Argentina	<.0001	<.0001	<.0001	0.0003

bermudagrass increased in ash production at a more rapid rate from 14 days until approximately 42 days. Once Jiggs bermudagrass peaked in ash production at approximately 45 days, ash production of this forage decreased.

Ash production of Tifton 9 bahiagrass resulted in a quadratic expression ($P < 0.05$), while Pensacola and Argentina had a cubic pattern of growth (Table 6). Argentina bahiagrass had a higher rate of ash production than Pensacola bahiagrass (Figure 4). Argentina bahiagrass had a higher peak in ash production than did either Pensacola or Tifton 9.

Crude Protein Composition and Production

There was no difference ($P > 0.05$) on the three bermudagrass cultivars and Argentina bahiagrass CP composition at the 14-d harvest (Table 7). Both Pensacola and Tifton-9 bahiagrasses had lower CP composition at the 14-d harvest. Crude protein composition of the bermudagrass cultivars was not different ($P > 0.05$) at 28 days of growth. Likewise, bahiagrass cultivars were similar ($P > 0.05$) in CP at this time. Crude protein composition of the bermudagrass cultivars were higher than the CP of the bahiagrass cultivars at 4 wk growth. Arthington and Brown (2005) reported similar results when they compared bermudagrass to limpograss and bahiagrass. Crude protein composition of Tifton 9 bahiagrass was similar to all of the other grasses ($P > 0.05$).

At the 42-d harvest, Russell bermudagrass and Pensacola bahiagrass had higher levels ($P < 0.05$) of CP than the other grasses (Table 7). Common bermudagrass had higher CP content ($P < 0.05$) than Argentina bahiagrass but was not different ($P > 0.05$) from Jiggs bermudagrass or Tifton 9 bahiagrass. There was no difference in the CP composition ($P > 0.05$) among Jiggs bermudagrass, Tifton 9 bahiagrass or Argentina bahiagrass. There was no difference in CP among the different grasses at 56 and 70 days of growth.

Table 7. Crude protein (%) of bermudagrass and bahiagrass cultivars harvested after different growth periods.

	Bermudagrass			Bahiagrass				
Days of growth	Russell	Common	Jiggs	Tifton-9	Pensacola	Argentina	SE	Prob
14	20.3^{a}	20.8^{a}	20.8^{a}	17.6^{b}	17.0^{b}	19.1^{a}	0.6	.0002
28	11.1^{a}	11.3^{a}	11.4^{a}	10.7^{ab}	10.3^{b}	10.1^{b}	0.3	.0092
42	9.0^{a}	8.7^{ab}	8.0^{bc}	8.2^{bc}	9.1^{a}	7.4^{c}	0.4	.0153
56	6.9	6.9	5.8	6.8	6.5	6.1	0.4	.2820
70	6.8	6.6	5.8	6.8	6.2	6.5	0.3	.2732

[abc] Row means with different superscripts are different ($P < 0.05$).

Arthington and Brown (2005) suggested that averaging over all grasses in their study, increased forage maturity was associated with 37.8% less CP concentration compared with harvesting at 4-wk growth. Similarly, we observed that there was a 39.9% decrease in CP when harvesting at 10 weeks of growth rather than at 4 weeks. According to Brown and Mislevy (1988), other researchers have reported that average tropical forage CP content decreases below 9% after 6 wk of summer growth. Likewise in our study, at the 42-d harvest, common, Jiggs, Tifton-9, and Argentina were all below 9% CP. Russell and Pensacola were reported as having 9.0 and 9.1% CP, respectively after 6 wks of growth. According to Gates et al. (2001), Pensacola bahiagrass exceeded Tifton-9 in CP concentrations on 5 different harvest dates. This was consistent with previous findings of Mislevy et al. (1990), who demonstrated that CP concentrations were higher in Pensacola than in Tifton-9 bahiagrass. Conversely, our data suggest that Pensacola and Tifton-9 were similar in CP concentrations accept at the 42-d harvest. Hill et al. (1993) reported that mean masticate analyses revealed similar CP for Tifton 78 and Tifton 85 in May, and July, but higher ($P < 0.05$) CP for Tifton 85 than for Tifton 78 in September. Sanderson et al. (1999) reported that crude protein concentrations decreased from 113 g kg $^{-1}$ at the May harvest to 79 g kg $^{-1}$ in the second regrowth harvest taken in July. It was also reported by Sanderson et al. (1999) that CP concentrations decreased as the final harvest was delayed. Twidwell et al. (1988) observed a decrease in CP from 170 to 100 g kg $^{-1}$ at ages ranging from 0 to 28 d after appearance of leaf material in switchgrass. These findings are similar to what was observed in the present research. This pattern was the result of plant aging, as forage quality of switchgrass typically decreases with maturity (Burns et al., 1997).

Russell bermudagrass produced the least amount ($P < 0.05$) of CP at d 14, while Argentina bahiagrass produced the most CP (Table 8). Jiggs bermudagrass produced more CP ($P < 0.05$) than Russell, common, Tifton 9, and Pensacola bahiagrass. Tifton 9 and Pensacola bahiagrass were similar ($P > 0.05$) in their CP production at 14-d harvest and produced more CP than common bermudagrass.

At the 28-d harvest, Jiggs bermudagrass produced the most CP followed by Russell bermudagrass and Argentina bahiagrass ($P < 0.05$) (Table 8). There was no difference ($P > 0.05$) in CP production among common bermudagrass, Tifton 9 bahiagrass, and Pensacola bahiagrass. Jiggs bermudagrass also produced more CP ($P < 0.05$) at the 42-d harvest than the other grasses, with production levels 12.4% and 14.1% higher than Russell and common bermudagrass, respectively. Russell bermudagrass, common bermudagrass, and Pensacola bahiagrass CP production were similar ($P > 0.05$) and these grasses had higher production ($P < 0.05$) than Tifton 9 and Argentina bahiagrass after 42 days of growth. There was no difference between Tifton 9 and Argentina bahiagrass ($P > 0.05$) in CP production at 42 days.

By d 56, Jiggs bermudagrass produced the most CP ($P < 0.05$), followed by Russell and common bermudagrass (Table 8). Harvested CP was not different ($P > 0.05$) among common bermudagrass, Tifton 9, and Argentina bahiagrass at the 56-d harvest. There was no difference ($P > 0.05$) between CP produced at 56 days between Pensacola and Argentina bahiagrass. Crude protein production was not different ($P > 0.05$) among any of the grasses at the 70-d harvest.

Table 8 Crude protein (kg/ha) of bermudagrass and bahiagrass cultivars harvested after different growth periods.

	Bermudagrass			Bahiagrass				
Days of growth	Russell	Common	Jiggs	Tifton-9	Pensacola	Argentina	SE	Prob.
14	66^{a}	120^{b}	252^{c}	179^{d}	193^{d}	328^{e}	14	<.0001
28	565^{a}	483^{b}	770^{c}	457^{b}	481^{b}	599^{a}	42	<.0001
42	602^{a}	590^{a}	687^{b}	512^{c}	575^{a}	498^{c}	29	0.0011
56	567^{a}	520^{ab}	620^{c}	487^{b}	362^{d}	449^{bd}	44	0.0054
70	520	430	516	520	466	577	40	0.1926

^{abcd}Row means with different superscripts are different ($P < 0.05$).

Common bermudagrass CP content was quadratic ($P < 0.001$), while Russell and Jiggs were cubic (Table 9). The prediction line for CP production of Jiggs bermudagrass increased at a higher rate and decreased at a higher rate than the prediction of CP production for Russell and common from 14 to 70 days (Figure 5). Russell and common followed similar patterns up to approximately 60 days when Russell's cubic function of this equation indicated an increase in production. The prediction lines estimated that Russell or common bermudagrass would not decrease in CP production as rapidly as Jiggs. All three equations suggest that CP production of the bermudagrass cultivars peaked between 35 and 40 days.

Table 9. P values for model and contrast analysis of crude protein (kg/ha) of bermudagrass and bahiagrass cultivars.

	Model	Linear	Quad	Cubic
Russell	<.0001	<.0001	<.0001	<.0001
Common	<.0001	<.0001	<.0001	0.079
Jiggs	<.0001	0.0006	<.0001	<.0001
Tifton 9	<.0001	<.0001	0.0014	0.0468
Pensacola	<.0001	0.0002	<0113	<.0001
Argentina	<.0001	0.0047	0.0841	<.0001

A cubic function ($P < 0.05$) was observed for CP production for all of the bahiagrass cultivars (Table 9). Argentina and Pensacola bahiagrass followed a similar pattern (Figure 6). Their prediction lines estimated that they both increased rapidly until approximately 30 days. These same prediction lines decreased after 30 days until approximately 60 days. The plotted line suggests that Argentina produced more CP than Pensacola. The prediction line for Tifton-9 bahiagrass suggested a slower rate of increased production and a slower decrease.

Neutral Detergent Fiber Composition and Production

Bahiagrass NDF composition was similar ($P > 0.05$) across the three cultivars at each of the different harvest times except for the d 42 harvest where Argentina had higher NDF levels ($P < 0.05$) than either Tifton 9 or Pensacola (Table 10). At the 14-d harvest time, Russell bermudagrass was higher ($P < 0.05$) than either common or Jiggs bermudagrass and was similar to the NDF composition of the three bahiagrass cultivars. Neutral detergent fiber composition was not different ($P > 0.05$) among the grasses at the 28-d harvest.

Russell and Jiggs bermudagrass had similar ($P > 0.05$) NDF composition at 42 days of growth and had higher NDF levels than the other grasses (Table 10). There was no difference ($P > 0.05$) among the three bahiagrass cultivars and common bermudagrass at the 42-d harvest. At 56 days of growth, NDF content of Russell bermudagrass was higher ($P < 0.05$) than all other grasses except Argentina bahiagrass. The NDF composition of Argentina bahiagrass was similar ($P > 0.05$) to all other grasses except common bermudagrass. There was no difference ($P > 0.05$) among common, Jiggs, Tifton 9, and Pensacola.

The bahiagrass cultivars were similar ($P > 0.05$) in NDF composition at 70 days of growth. Common bermudagrass had the least amount ($P < 0.05$) of NDF during this period (Table 10). Russell and Jiggs were also similar ($P > 0.05$) to each other as well as to the bahiagrass cultivars at 70 days.

Neutral detergent fiber composition of bermudagrass and bahiagrass cultivars at 4 wk

Table 10. Neutral detergent fiber (%) of bermudagrass and bahiagrass cultivars harvested after different growth periods.

	Bermudagrass			Bahiagrass				
Days of growth	Russell	Common	Jiggs	Tifton-9	Pensacola	Argentina	SE	Prob
14	63.5^{a}	57.8^{b}	58.1^{b}	63.0^{a}	64.3^{a}	60.7^{ab}	0.6	<.0001
28	67.9	62.0	63.8	64.3	67.8	63.4	0.7	.1067
42	69.6^{a}	66.2^{b}	68.9^{a}	67.0^{b}	65.6^{b}	65.6^{b}	0.6	.0001
56	69.6^{a}	65.4^{b}	67.9^{bc}	67.1^{bc}	66.9^{bc}	67.7^{ac}	0.8	.0186
70	68.9^{a}	66.9^{b}	70.6^{a}	69.1^{a}	70.5^{a}	68.8^{a}	0.8	.0196

^{abc}Row means with different superscripts are different ($P < 0.05$).

growth showed no significant difference ($P > 0.05$). Russell, Jiggs, and bahiagrass cultivars at 10 wk growth were similar ($P > 0.05$) in NDF composition to each other. These findings contradict what Arthington and Brown (2005) observed. They observed that NDF concentrations were least in bahiagrass when compared to bermudagrass and limpograss at 4 and 10 wk growth. Johnson et al. (1991) reported a linear increase ($P < 0.01$) of 2.8% in bahiagrass NDF concentration across the harvest season. This reflects the findings of the present research. A linear increase in NDF composition was shown, but it was approximately 9.7%. Henderson and Robinson (1982) reported a positive relationship between NDF and temperature for bermudagrass, while also reporting a negative relationship between NDF and temperature in bahiagrass. Our data agrees with their observations for bermudagrass, but contradicts their results for bahiagrass. Sanderson et al. (1999) reported concentrations of NDF increased from 648 g kg $^{-1}$ to 683 g kg $^{-1}$ during the July harvest. Twidwell et al. (1988) also showed that NDF concentrations increased from 670 g kg $^{-1}$ to 725 g kg $^{-1}$ at ages that ranged from 0 to 28 days. According to Gekara et al. (2005), the herbage on high sward height pasture was higher ($P < 0.06$) in NDF and ADF than herbage on low sward height. Philips et al. (2002) reported that kenaf pellets were similar to alfalfa pellets in NDF concentration (44.4 vs. 40.2%), but contained less ADF (22.1 vs. 32.6%) than alfalfa pellets. The chemical composition of kenaf hay is greatly influenced by harvesting date (Philips et al., 1999).

Comparisons of leaves and stems show a positive relationship between NDF content and resistance to particle size breakdown, whereas comparisons of forages varying in maturity tend to show the opposite effect. Stems have been reported to be more resistant than leaves to particle size reduction by chewing during eating for Pangola and Rhodes grasses (Poppi et al., 1981) and for ryegrass and alfalfa (McLeod and Minson, 1988). Laredo and Minson (1975) found higher voluntary dry matter intake and lower ruminal retention times for leaves than for stems for three different grasses fed to sheep. Stem NDF and lignin contents are higher than for leaves, although the differences for grasses are much less than for alfalfa. Resistance to particle size breakdown by chewing may decrease as forages mature. Poppi et al. (1981) reported that 12-wk regrowth of Pangola grass and Rhodes grass was reduced to a greater extent by initial mastication than 6-wk regrowth for both leaves and stems, resulting in a lower proportion of large particles in the reticulorumen of sheep and cattle for the 12-wk regrowth. Fiber (NDF) content increased with maturity of the Rhodes grass only, but lignin content increased with maturity for both grasses. Ulyatt (1983) evaluated particle size reduction by chewing during eating for perennial ryegrass at two stages of maturity. The more-mature ryegrass had higher cell-wall content and lower digestibility and was reduced to a greater degree by chewing than the less-mature ryegrass. The increased particle size reduction during eating as forages mature may be due to an increased "brittleness" as suggested by Ulyatt (1983), possibly due to greater lignification of the cell wall.

Neutral detergent fiber production was the highest ($P < 0.05$) with Argentina bahiagrass at d 14 (Table 11). There was no difference ($P > 0.05$) in NDF production between Russell and common bermudagrass after 14 days of growth, although both produced less NDF than Jiggs bermudagrass, Tifton 9, and Pensacola bahiagrass. Jiggs, Tifton 9, and Pensacola were not different ($P > 0.05$) in their NDF production. Jiggs bermudagrass produced ($P < 0.05$) approximately 53% more NDF than common bermudagrass at 14 days.

At the 28-d harvest, there was no difference ($P > 0.05$) in NDF production between common bermudagrass and Tifton 9 bahiagrass (Table 11). Jiggs bermudagrass produced ($P < 0.05$) approximately 25% more NDF than Pensacola bahiagrass. Argentina bahiagrass produced more ($P < 0.05$) NDF than common bermudagrass at 28 days.

Table 11. Neutral detergent fiber (kg/ha) of bermudagrass and bahiagrass cultivars harvested after different growth periods.

	Bermudagrass			Bahiagrass				
Days of growth	Russell	Common	Jiggs	Tifton-9	Pensacola	Argentina	SE	Prob
14	210^{a}	330^{a}	705^{b}	644^{b}	727.0^{b}	1042^{c}	48	<.0001
28	3448^{a}	2648^{b}	4281^{c}	2746^{b}	3210.4^{ab}	3775^{ac}	253	0.0006
42	4673^{a}	4519^{a}	5947^{b}	4229^{a}	4114.4^{a}	4428^{a}	216	<.0001
56	5684	4969	7268	4798	3786.2	5016	343	<.0001
70	5291	7782	6340	5330	5298.5	6069	331	0.0052

^{abc}Row means with different superscripts are different ($P < 0.05$).

The bahiagrass cultivars were similar ($P > 0.05$) in NDF production at 42 days. Russell and common bermudagrass were also similar ($P > 0.05$) to the bahiagrass cultivars in NDF production, but were different ($P < 0.05$) when compared to Jiggs bermudagrass (Table 11). Jiggs bermudagrass produced ($P < 0.05$) more NDF than all other cultivars at the 42-d harvest. Jiggs produced more ($P < 0.05$) NDF than the other grasses at 56 and 70 days of growth (Table 11). Pensacola bahiagrass was the lowest in production of NDF ($P < 0.05$) of all the cultivars at 56 days of growth. There was no difference ($P > 0.05$) in NDF production when comparing Russell, common, Tifton 9, and Argentina grasses.

By d 70, Jiggs bermudagrass and Argentina bahiagrass were similar in NDF production (Table 11). Common bermudagrass produced the least amount ($P < 0.05$) of NDF during this period. Jiggs produced approximately 16% more ($P < 0.05$) NDF than did Tifton 9.

Bermudagrasses are day-length sensitive forages and certain hybrids produce an abundance of stems and leaves in the spring, followed by more vegetative growth later in the season. Hill et al. (1993) reported that NDF values were higher for both Tifton 78 and Tifton 85 relative to Coastal bermudagrass. The increased proportion of robust stems produced by Tifton 85 probably contributed to the increased NDF observed in forage samples. Both Tifton 78 and Tifton 85 are larger stemmed plants than Coastal, which may account for increased NDF for these hybrids (Hill et al., 1993). These findings are similar to our observations when comparing Russell and Jiggs to common bermudagrass.

Contrast analysis of NDF production within forage indicated a quadratic function ($P < 0.001$) for all bermudagrass cultivars (Table 12). Jiggs bermudagrass had the largest increase in NDF production in the first 42 days of growth (Figure 7). Russell and common followed a similar trend up to approximately 42 days. After 42 days, the prediction lines indicated that Russell began to produce larger quantities of NDF than common bermudagrass. All 3 bermudagrass cultivars reached their peak predictions by approximately d 60 of growth. While NDF production of Pensacola and Argentina bahiagrass resulted in a cubic expression ($P < 0.05$), Tifton-9 bahiagrass had a quadratic pattern of growth (Table 12). The prediction lines indicated that Pensacola and Argentina followed a similar trend (Figure 8). The prediction line for Pensacola remains flat from 40 to 60 days and increased the last ten days of the period. Argentina's prediction line continued to increase slightly from 40 to 60 days. In contrast, NDF of Tifton 9 increased up to about 62 days of growth before leveling out.

Table 12. P values for model and contrast analysis for NDF (kg/ha) of bermudagrass and bahiagrass cultivars.

	Model	Linear	Quad	Cubic
Russell	<.0001	<.0001	<.0001	0.4379
Common	<.0001	<.0001	<.0001	0.5953
Jiggs	<.0001	<.0001	<.0001	0.6824
Tifton 9	<.0001	<.0001	<.0001	0.5720
Pensacola	<.0001	<.0001	0.0002	<.0001
Argentina	<.0001	<.0001	<.0001	0.0003

Acid Detergent Fiber Composition and Production

Bermudagrass cultivars had less ADF ($P < 0.05$) composition when compared to the bahiagrass cultivars at 14 days of growth (Table13). Russell and Jiggs bermudagrasses were similar ($P > 0.05$) in ADF composition at 14 days. Common bermudagrass ADF was the lowest

($P < 0.05$) when compared to the other bermudagrass cultivars. Tifton 9 and Pensacola bahiagrass had similar ($P > 0.05$) ADF compositions at 14 days. Argentina bahiagrass was the lowest ($P < 0.05$) in ADF composition when compared to the other bahiagrass cultivars. Argentina bahiagrass had the lowest % ADF of the three bahiagrass cultivars.

At d 28, common bermudagrass had the lowest ($P < 0.05$) ADF composition of all the other cultivars (Table 13). The bahiagrass cultivars as well as Russell and Jiggs bermudagrass were similar ($P > 0.05$) in ADF composition at 28 days of growth (Table 13). Common and Jiggs bermudagrass was similar ($P > 0.05$) in ADF composition at 42 days of growth. Russell bermudagrass and the bahiagrass cultivars were not different ($P > 0.05$) when compared at the 42-d harvest.

Common bermudagrass continued to maintain the advantage of being the most digestible forage at 56 and 70 days of growth (Table 13). The bahiagrass cultivars were also not different ($P > 0.05$) in ADF composition when compared to each other at 56 and 70 days of growth. At 56 days, Russell and Jiggs bermudagrass were not different ($P > 0.05$) in ADF composition, however, at 70 days of growth, Russell bermudagrass ADF composition was lower ($P < 0.05$) than Jiggs.

The ADF composition of bermudagrass and bahiagrass was similar to the findings of other researchers. It was observed that after averaging across the harvest dates, bahiagrass cultivars contained 9 % more ADF than bermudagrass cultivars. Johnson et al. (2001) observed that bahiagrass contained 6.4 % more ($P < 0.05$) ADF than bermudagrass and 8.3 % more ADF than stargrass when averaged across all harvest dates. Brown and Pitman (1991) also reported higher concentrations of ADF in bahiagrass compared with other warm-season grasses.

Table 13. Acid detergent fiber (%) of bermudagrass and bahiagrass cultivars harvested after different growth periods.

	Bermudagrass			Bahiagrass				
Days of growth	Russell	Common	Jiggs	Tifton-9	Pensacola	Argentina	SE	Prob
14	28.7^{a}	24.7^{b}	27.4^{a}	33.0^{c}	34.7^{c}	31.0^{d}	0.7	<.0001
28	33.4^{a}	28.4^{b}	34.4^{a}	34.3^{a}	33.4^{a}	32.9^{a}	0.9	.0008
42	36.8^{a}	30.2^{b}	35.9^{a}	35.4^{a}	35.8^{a}	34.4^{a}	0.8	<.0001
56	34.3^{a}	29.6^{b}	35.0^{a}	36.3^{a}	36.3^{a}	35.9^{a}	0.8	<.0001
70	33.7^{a}	29.4^{b}	36.5^{c}	38.3^{c}	38.1^{c}	36.6^{c}	0.6	<.0001

^{abc}Row means with different superscripts are different ($P < 0.05$).

Evers et al. (2004) reported that bahiagrass cultivars had a higher initial ADF concentration than bermudagrass cultivars in a stockpiled situation. Those results are similar to what our research showed even though the present research was conducted during the growing season. Evers et al. (2004) also reported that during the end of the stockpiled phase, some of the bermudagrass cultivars had ADF concentrations similar to bahiagrass. Our 70-d harvest data agrees with their observations even though the two trials were during different seasons of growth.

ADF production was the highest ($P < 0.05$) in Argentina bahiagrass at the 14-d harvest. There was no difference ($P > 0.05$) in Russell and common bermudagrass ADF production (Table 14). These two cultivars produced the least amount of ADF at 14 days. Jiggs, Tifton 9, and Pensacola were also very similar ($P > 0.05$) to each other when comparing the ADF production.

ADF production was the highest ($P < 0.05$) in Jiggs bermudagrass from 28 days through 70 days of growth (Table 14). There was a difference ($P < 0.05$) in ADF production when comparing Russell bermudagrass to common and Jiggs at 28 days of growth. Common bermudagrass produced the least amount ($P < 0.05$) of ADF at 28 days of growth. There was a difference in ADF production ($P < 0.05$) when comparing Russell bermudagrass to common bermudagrass at 42 days. Common produced less ADF than Russell during this period of growth. The bahiagrass cultivars were similar ($P > 0.05$) to each other and only different ($P < 0.05$) from Jiggs bermudagrass at 42 days of growth (Table 14).

At 56 days of growth, Russell bermudagrass and Argentina bahiagrass were similar ($P > 0.05$) in ADF production. Common bermudagrass and Pensacola bahiagrass were also similar ($P > 0.05$) to each other when compared at the 56-d harvest (Table 14). Tifton 9 bahiagrass was only different from ($P < 0.05$) Jiggs bermudagrass when compared at 56 days.

Table 14. Acid detergent fiber (kg/ha) of bermudagrass and bahiagrass cultivars harvested after different growth periods.

	Bermudagrass			Bahiagrass				
Days of growth	Russell	Common	Jiggs	Tifton-9	Pensacola	Argentina	SE	Prob
14	95^{a}	141^{a}	333^{b}	338^{b}	391^{b}	532^{c}	25	<.0001
28	1695^{ab}	1230^{c}	2309^{d}	1470^{ac}	1600^{a}	1956^{b}	133	<.0001
42	2469^{a}	2062^{b}	3103^{c}	2230^{ab}	2239^{ab}	2321^{ab}	117	<.0001
56	2805^{s}	2257^{b}	3750^{c}	2599^{ab}	2067^{b}	2650^{a}	191	<.0001
70	2589^{a}	1941^{b}	3272^{c}	2963^{c}	2870^{c}	3227^{c}	171	<.0001

^{abc}Row means with different superscripts are different ($P < 0.05$).

On d 70, Jiggs bermudagrass and the bahiagrass cultivars were similar ($P > 0.05$) in ADF production (Table 14). The ADF production of Russell bermudagrass was higher than ($P < 0.05$) common bermudagrass at 70 days of growth. Common bermudagrass had the lowest ($P < 0.05$) amount of ADF production through 70 days of growth.

A contrast analysis of ADF production within forage indicated a quadratic function ($P < 0.001$) for all bermudagrass cultivars (Table 15). Prediction lines indicated that Jiggs bermudagrass should produce more ADF than Russell and common throughout the growing period (Figure 9). All three bermudagrass cultivars appeared to peak in ADF production between 50 and 60 days of growth

Table 15. P values for model and contrast analysis for ADF (kg/ha) of bermudagrass and bahiagrass cultivars.

	Model	Linear	Quad	Cubic
Russell	<.0001	<.0001	<.0001	0.5068
Common	<.0001	<.0001	<.0001	0.6395
Jiggs	<.0001	<.0001	<.0001	0.8949
Tifton 9	<.0001	<.0001	0.0098	0.5359
Pensacola	<.0001	<.0001	0.0006	0.0002
Argentina	<.0001	<.0001	<.0001	<.0001

While ADF production of Tifton 9 resulted in a quadratic expression ($P < 0.05$), both Pensacola and Argentina bahiagrass had a cubic pattern of growth (Table 15). The prediction line for Tifton 9 was curvilinear until 50 days where it starts to level off (Figure 10). The predicted path for Pensacola and Argentina was very similar until approximately 28 days. At this point, Argentina appeared to increase in ADF production compared to Pensacola.

Season of Harvest X Cut Time

<u>Dry Matter Composition and Production</u>

The early- and mid-season harvest was similar ($P > 0.05$) in DM composition when compared to the late season harvest at 14 days of growth (Table 16). The late season harvest of Russell bermudagrass contained the least amount ($P < 0.05$) of DM. Russell bermudagrass harvested during the early-season had higher DM composition ($P < 0.05$) from 28 days through 56 days of growth (Table 16). There was no difference ($P > 0.05$) in DM composition among the three different seasons of harvest from 28 to 56 days of growth. At 42 days of growth, the mid-season harvest had less ($P < 0.05$) DM composition than did the late season. At 56 days, the mid-season harvest had more ($P < 0.05$) composition than did the late season. The mid- and late-season harvest was not different ($P > 0.05$) in DM composition when compared to each other at

Table 16. Dry matter (%) of Russell bermudagrass harvested after different growth periods with different initial harvest dates.

Days of Growth	June 21	July 19	August 16	SE	Prob
14	28.6^a	28.5^a	18.2^b	1.07	<.0001
28	33.9^a	29.9^b	25.6^c	.8	<.0001
42	41.2^a	22.2^b	34.4^c	.8	<.0001
56	50.2^a	40.4^b	35.1^c	.5	<.0001
70	30.3^a	43.4^b	41.6^b	.8	<.0001

^{abc}Row means with different superscripts are different ($P < 0.05$).

70 days of growth. The early-season had the least amount ($P < 0.05$) of DM composition at 70 days (Table 16).

Dry matter production was less than 2000 kg/ha at the 14-d harvest (Table 17) for all the seasons and would not be economical for commercial harvest at that time. There was no difference ($P > 0.05$) among the three different start dates when harvested at 14 days. At 28 days of growth, there was no difference ($P > 0.05$) in the DM production between the early and mid-season harvest, but the late-season harvest produced less ($P < 0.05$) DM.

The early season harvest produced the most ($P < 0.05$) DM production after 42 days of growth followed by the mid-season harvest, then the late season harvest. There was no difference ($P > 0.05$) when comparing the early and mid- season harvest DM production at 56 days (Table 17), while the late season harvest produced the least amount ($P < 0.05$) of DM production. A similar effect was observed after 70 days of growth.

Table 17. Dry matter (kg/ha) of Russell bermudagrass harvested after different growth periods with different initial harvest dates.

Days of Growth	June 21	July 19	August 16	SE	Prob
14	329	563	214	104	0.0864
28	5076^{a}	5253^{a}	2670^{b}	308	<.0001
42	6713^{a}	5296^{b}	4278^{c}	417	0.0032
56	8175^{a}	7422^{a}	5524^{b}	360	0.0003
70	7667^{a}	7960^{a}	5758^{b}	418	0.0039

^{abc}Row means with different superscripts are different ($P < 0.05$)

The early- and late-season harvest DM production was expressed by a quadratic function ($P < 0.001$), while the mid-season harvest DM production was expressed by a cubic function (Table 18). The prediction lines indicated that the early and late season harvested DM production were similar until about 30 days of growth, where the early season harvest increased at a faster rate until about 60 days (Figure 11). Both the early season and mid-season harvested forages increased in DM production at a faster rate compared to the late season. The early season harvest peaks out at 55 days. The prediction for the late season peak is not until 68 days. These findings are similar to those of Johnson et al. (2001) who observed that forage mass had a quadratic relationship with harvest date, with peak forage mass occurring in late June and July. According to Adeli (2005), forage DM, CP, NDF and ADF levels peaked in the July harvest and then declined.

Table 18. P values for model and contrast analysis for DM production (kg/ha) of Russell bermudagrass harvested at different starting dates.

First harvest, date	Model	Linear	Quad	Cubic
June 21	<.0001	<.0001	<.0001	0.3033
July 19	<.0001	<.0001	0.0006	0.0309
August 16	<.0001	<.0001	<.0001	0.8239

Late season harvest of warm-season perennial grasses has been shown to have lower amounts of DM production. Our data was similar to Parrish and Wolf (1993) who reported decreases in biomass yield in switchgrass with late final autumn harvest. They suggested that switchgrass remobilizes and translocates C and N reserve compounds from the aerial portion to the belowground portion of the plant during the autumn, partially accounting for the yield reduction. Other researchers have reported changes in carbohydrate concentrations and shoot weight of perennial warm-season grasses that support the hypothesis of Parrish and Wolf (1993). For example, Anderson et al. (1989) measured peak concentrations of total nonstructural carbohydrate in the above- and belowground portions of switchgrass in September.

Ash Composition and Production

Ash composition did not differ ($P > 0.05$) between seasons of harvest (Table 19). Ash production was similar at14 days of growth and at 42 days of growth. At 28 days, there was no difference ($P > 0.05$) in ash production between the early season and mid-season harvest. The late season harvest produced the least amount ($P < 0.05$) of ash. This trend continued on through 56 and 70 days of growth (Table 20).

Table 19. Ash (%) of Russell bermudagrass harvested after different growth periods with different initial harvest dates.

Days of Growth	June 21	July 19	August 16	SE	Prob
14	7.5	7.7	8.5	3.4	0.1376
28	6.4	6.3	7.2	0.4	0.3165
42	5.7	6.0	6.3	.5	0.6999
56	5.0	5.3	5.8	.3	0.2617
70	4.8	5.3	5.0	.2	.3520

^{abc}Row means with different superscripts are different ($P < 0.05$).

Table 20. Ash (kg/ha) of Russell bermudagrass harvested after different growth periods with different initial harvest dates.

Days of Growth	June 21	July 19	August 16	SE	Prob
14	25	43	18	8	0.1094
28	321^a	322^a	193^b	18	0.0002
42	382	320	268	43	0.2155
56	403^a	394^a	319^b	17	0.0062
70	364^a	425^a	289^a	29	0.0151

^{abc}Row means with different superscripts are different ($P < 0.05$).

The early and mid-season harvest ash production was expressed by a cubic function ($P < 0.05$), and the late season harvest was expressed by a quadratic function (Table 21).

Table 21. P values for model and contrast analysis for ash (kg/ha) of Russell bermudagrass harvested at different starting dates.

First harvest, date	Model	Linear	Quad	Cubic
June 21	<.0001	<.0001	<.0001	0.0450
July 19	<.0001	<.0001	0.0022	0.0318
August 16	<.0001	<.0001	<.0001	0.7154

The early and mid-season prediction lines follow a similar pattern until approximately 30 days. At this point, the early season harvest was predicted to produce more ash until approximately 60 days. At 60 days, the early season harvest tended to decrease and the mid-season harvest tended to increase over and beyond the early season (Figure 12). The late season harvest is not predicted to peak in production until approximately 55 days.

Crude Protein Composition and Production

At 14 days of growth, the early season harvested bermudagrass had the highest ($P < 0.05$) CP composition (Table 22). There was no difference ($P > 0.05$) between the mid and late season harvested bermudagrass. A similar response was observed at the 28-d harvest, however, at the 28-d harvest, the early cut forage had the lowest CP composition. From 42 to 70 days of growth, there is no difference ($P > 0.05$) among the season of harvest. Crude protein production at the three different seasons of harvest was not different ($P > 0.05$) after 14 days of growth (Table 23).

Table 22. Crude protein (%) of Russell bermudagrass harvested after different growth periods with different initial harvest dates.

Days of Growth	June 21	July 19	August 16	SE	Prob
14	20.3^{a}	17.7^{b}	18.3^{b}	0.6	0.0265
28	11.1^{a}	12.6^{b}	12.5^{b}	0.4	0.0167
42	9.0	8.1	7.5	0.5	0.1484
56	6.9	6.7	6.3	0.3	0.3770
70	6.8	6.4	5.7	0.4	0.2274

^{abc}Row means with different superscripts are different ($P < 0.05$).

Table 23. Crude protein (kg/ha) of Russell bermudagrass harvested after different growth periods with different initial harvest dates.

Days of Growth	June 21	July 19	August 16	SE	Prob
14	66	99	39	18	0.1065
28	564^a	665^a	333^b	43	0.0002
42	602^a	420^b	317^c	32	<.0001
56	566^a	500^a	349^b	35	0.0016
70	520^a	516^a	331b	48	0.0213

^{abc}Row means with different superscripts are different ($P < 0.05$).

There was no difference ($P > 0.05$) in CP production when comparing the early to mid-season harvest at 28 days of growth. The late season harvest at 28 days produced the least amount ($P < 0.05$) of CP. At 42 days of growth, the CP production was different ($P < 0.05$) among the different seasons of harvest, with the early harvest producing more CP than the mid-harvest, and the mid-harvest producing more CP than the late harvest. For 56 and 70 days of growth, the early and mid-season harvest was similar ($P > 0.05$), and the late season harvest produced the least amount ($P < 0.05$) of CP. Sumner et al. (1991) reported a 13.8% depression in crude protein concentration of bahiagrass regrowth in July compared with a June harvest. Additionally, Rusland et al. (1988) reported a 25% loss in limpograss crude protein from early June to late July.

Contrast analysis of CP production within forage indicated a cubic function ($P < 0.05$) for the three seasons of harvest (Table 24). The early season harvest prediction line for peak production was around 36-38 days (Figure 13). The mid-season harvest prediction for peak

Table 24. P values for model and contrast analysis for crude protein (kg/ha) of Russell bermudagrass harvested at different starting dates.

First harvest, date	Model	Linear	Quad	Cubic
June 21	<.0001	<.0001	<.0001	<.0001
July 19	<.0001	0.0005	0.0006	0.0001
August 16	<.0001	<.0001	<.0001	0.0007

production was around 32 days. The mid-season harvest was predicted to decrease at a faster rate from approximately 28 days before starting to increase at approximately 60 days. The early season harvest did not decrease as fast in that stage of growth. The late season harvest prediction line indicated that it will be the least productive throughout the growing season.

<u>Neutral Detergent Fiber Composition and Production</u>

There was no difference ($P > 0.05$) among NDF composition for the three seasons of harvest at 14 days of growth. The mid-season harvest had the least amount ($P < 0.05$) of NDF composition (Table 25). This would suggest that the mid-season harvested bermudagrass should have the highest amount of intake. The early season harvested bermudagrass was composed of the highest amount ($P < .05$) of NDF at 14 days of growth. There was no difference ($P > 0.05$) in NDF content of the 3 harvest periods for 28 and 70-d harvest times (Table 25). At 42 days of growth, the late-season harvested bermudagrass had the least amount ($P < 0.05$) of NDF composition, and the mid-season harvested bermudagrass had the largest amount ($P < 0.05$) of NDF. The mid-season harvested bermudagrass contained more NDF ($P < 0.05$) than the other

Table 25. Neutral detergent fiber (%) of Russell bermudagrass harvested after different growth periods with different initial harvest dates.

Days of Growth	June 21	July 19	August 16	SE	Prob
14	63.5^{a}	56.5^{b}	60.4^{c}	0.9	0.0002
28	67.9	66.5	65.1	0.8	0.0536
42	69.6^{a}	72.4^{b}	66.8^{c}	0.6	<.0001
56	70.0^{a}	71.9^{b}	68.5^{a}	0.5	0.0005
70	68.9	68.5	68.6	0.6	.9156

^{abc}Row means with different superscripts are different ($P < 0.05$).

seasons of harvest at 56 days of growth. There was no difference between ($P > 0.05$) NDF composition of the early and late season harvested forage at 56 days.

NDF production at 14 days of growth was not different ($P > 0.05$) (Table 26).

Table 26. Neutral detergent fiber (kg/ha) of Russell bermudagrass harvested after different growth periods with different initial harvest dates.

Days of Growth	June 21	July 19	August 16	SE	Prob
14	210	323	127	64	0.1283
28	3448^{a}	3504^{a}	1735^{b}	228	<.0001
42	4674^{a}	3825^{b}	2856^{c}	286	0.0017
56	5683^{a}	5334^{a}	3785^{b}	245	0.0001
70	5291^{a}	5458^{a}	3945^{b}	298	0.0048

^{abc} Row means with different superscripts are different ($P < 0.05$).

There was no difference in NDF production at 28, 56, and 70 days of growth ($P > 0.05$) when comparing the early and mid-season harvested bermudagrass. The late-season harvested forage had the least amount of NDF production ($P < 0.05$) at 28, 42, 56, and 70 days of growth. At 42 days of growth, all three seasons of harvest were different ($P < 0.05$) for NDF production.

The three seasons of harvest were all expressed as a quadratic function ($P < 0.05$) for NDF production (Table 27). The prediction lines for both the early and mid-season harvest were almost identical (Figure14). The early-season harvest was predicted to produce slightly more NDF from 25 days until 60 days of growth when compared to the mid-season. The late-season harvest continues to be the least productive throughout the entire growing season.

Table 27. P values for model and contrast analysis for NDF (kg/ha) of Russell bermudagrass harvested at different starting dates.

First harvest, date	Model	Linear	Quad	Cubic
June 21	<.0001	<.0001	<.0001	0.4379
July 19	<.0001	<.0001	0.0002	0.1300
August 16	<.0001	<.0001	<.0001	0.5643

Acid Detergent Fiber Composition and Production

At 14 days of growth, early- and late-season harvested Russell bermudagrass were similar ($P > 0.05$) in ADF composition. The mid-season harvest had the least amount of ADF at 14 days (Table 28). This would suggest that the July 19 harvested Russell bermudagrass would have the greatest amount of digestibility. The early- and mid-season harvested Russell was similar ($P > 0.05$) in ADF composition at 28 days of growth. The late-season harvested Russell is different ($P < 0.05$) from the early- and mid-season at 28 days. From 42 through 70 days of

Table 28. Acid detergent fiber (%) of Russell bermudagrass harvested after different growth periods with different initial harvest dates.

Days of Growth	June 21	July 19	August 16	SE	Prob
14	28.7^{a}	24.4^{b}	27.5^{a}	0.7	0.0010
28	33.4^{a}	33.7^{a}	31.9^{b}	0.5	0.0430
42	36.8	39.0	32.9	0.6	<.0001
56	34.3	35.4	34.5	0.6	0.5141
70	33.7	34.8	36.4	0.9	0.1510

[abc]Row means with different superscripts are different ($P < 0.05$).

growth, the model suggest that there was no difference among ($P > 0.05$) the three seasons of harvest.

There was no difference ($P > 0.05$) in ADF production after 14 days of growth among the three different seasons of harvest (Table 29). The late-season harvest is lower ($P < 0.05$) in ADF production than the early- and mid-season harvested Russell bermudagrass at 28 days. All three seasons of harvest were different ($P < 0.05$) in ADF production at 42 days of growth. The highest amount of ADF produced was in the early-season harvested Russell at 42 days. The least amount of ADF produced at 42 days of growth was in the late-season harvest. There was no difference in ADF production ($P > 0.05$) for the early- and mid-season harvested forage at 56 and 70 days of growth. The late season harvested forage continued to produce the least amount of ADF at 56 and 70 days of growth.

The three seasons of harvest were expressed in a quadratic function ($P < 0.001$) for ADF production (Table 30). The early- and mid-season prediction line follows a similar pattern to about 35 days. After 35 days of growth, the early-season harvested Russell continued to increase

Table 29. Acid detergent fiber (kg/ha) of Russell bermudagrass harvested after different growth periods with different initial harvest dates.

Days of Growth	June 21	July 19	August 16	SE	Prob
14	95	142	59	30	0.1755
28	1696^a	1761^a	853^b	91	<.0001
42	2469^a	2057^b	1403^c	150	0.0006
56	2805^a	2623^a	1902^b	127	0.0003
70	2589^a	2762^a	2087^b	151	0.0172

^{abc} Row means with different superscripts are different ($P < 0.05$).

Table 30. P values for model and contrast analysis for ADF (kg/ha) of Russell bermudagrass harvested at different starting dates.

First harvest, date	Model	Linear	Quad	Cubic
June 21	<.0001	<.0001	<.0001	0.5068
July 19	<.0001	<.0001	<.0001	0.0583
August 16	<.0001	<.0001	<.0001	0.7636

in ADF production (Figure 15). At approximately 60 days of growth, the ADF production of the early-season Russell began to decrease. The early-season harvest produced more ADF than did the mid-season harvest. The late-season harvest was predicted to be the lowest producing throughout the entire growing period. The late-season harvested Russell bermudagrass was predicted to increase in ADF production from 14 days of growth until 70 days of growth.

Chapter V

Summary and Conclusion

In the southern United States, researchers have shown that bermudagrass and bahiagrass can both be a nutritional and productive forage if managed and harvested at the proper time. If these forages are not managed properly, the nutritional value of the forages will decline rapidly. These forages can be managed properly with extensive management practices such as harvesting forage at the optimum time.

Dry matter composition was lower in the bahiagrass cultivars than the bermudagrass cultivars. The bermudagrass cultivars continued to increase in DM composition until approximately 56 days. The higher amounts of DM in bermudagrass varieties were mainly due to the increased amount of leaf-to-stem ratio found in bermudagrass. The bahiagrass was more variable in its DM composition.

The bahiagrass cultivars produced more DM during the first 14 days of growth than the bermudagrass cultivars. This was expected due to the fact that the bahiagrass varieties had faster regrowth post-cutting prior to the start of the project. At 28 days of growth, Jiggs and Argentina were similar ($P < 0.05$) in DM production but were greater than common, Russell, Tifton 9, and Pensacola. After 42 days, Jiggs bermudagrass produced the greatest amount ($P < 0.05$) of DM. Jiggs maintained that advantage in DM production through d 70 and Pensacola became the lowest producing ($P < 0.05$) in DM.

Jiggs bermudagrass contained the highest amount of ash at 14 days of growth. After the initial 2 weeks, all six cultivars were very similar in ash composition. The six different cultivars continued to decrease in ash composition as they matured.

Bermudagrass cultivars had the highest ($P < 0.05$) CP composition for the 14 and 28-day harvest. Bahiagrass cultivars were considered medium to high quality in CP for the first six weeks of growth. After six weeks of growth, bermudagrass and bahiagrass cultivars were below the minimum CP recommended for mature, gestating cattle. At six weeks of growth, Jiggs and Argentina had the lowest CP composition. These two forages were considered to be the highest producing and fastest growing among the six cultivars. Argentina bahiagrass produced significantly higher amounts ($P< 0.05$) of CP during the first two weeks of growth. Jiggs bermudagrass took over that advantage from d 28 until d 56.

NDF composition was the lowest in the common and Jiggs bermudagrass after the 14-day harvest. The NDF composition continued to increase and remained similar to one another as the forages matured. The Jiggs bermudagrass and Pensacola bahiagrass had the highest amounts of NDF after 70-days of growth. Argentina produced the most NDF during the first two weeks of growth. From that time on, Jiggs bermudagrass produced the most NDF. Russell produced the least amount of NDF at two weeks of growth followed by common at four weeks. Pensacola bahiagrass produced the least amount ($P < 0.05$) of NDF from wk 6 to wk 10.

Common bermudagrass had the least amount of ADF throughout the entire growing period. Bermudagrass cultivars were significantly lower ($P < 0.05$) in ADF composition than bahiagrass cultivars at d 14. From d 28 to d 56, Russell, Jiggs, and the bahiagrass cultivars were similar ($P > 0.05$) in ADF composition. After 10 wks of growth, Jiggs bermudagrass continued the trend of being similar ($P > 0.05$) to the bahiagrass cultivars for ADF composition. During the first two weeks of growth, Argentina bahiagrass produced a significantly ($P < 0.05$) higher amount of ADF when compared to any other cultivar. From that point on until d 42, Jiggs bermudagrass became the significantly highest ($P < 0.05$) producer of ADF. Producing the largest amount of ADF is not a positive aspect. Having the highest amount of ADF means that a cultivar would produce the least amount of digestible material at that stage of maturity.

Russell bermudagrass that was harvested during the early- and mid-season consisted of the highest percent DM and also had the most DM production. The late season Russell contained the least amount of DM. Ash composition was very similar throughout the different harvest seasons for Russell. CP composition was the highest during the first two weeks of growth in the early-season forage. CP was the lowest in the early-season forage at 28-days of growth. This could have been due to a drastic increase in temperature. After 28-days, there was no difference in the CP composition of the forage whether it was harvested during the early-, mid-, or late-season. NDF and ADF composition was higher in the early- and mid-season harvested forage.

Bermudagrass and bahiagrass play a vital role in forage production in Louisiana. These two forages are widely used in majority of the beef operations in Louisiana. It has been shown in this research that both forages are excellent choices for grazing and hay production if managed properly. Jiggs bermudagrass has been shown in this research to produce the greatest amounts of DM production and still maintain medium quality (9% CP) if harvested at approximately 34-35 days of growth. If a producer was looking for forage to rotationally graze cattle on, Argentina bahiagrass could be considered due to the fact that it was predicted to produce similar amounts of DM and CP to Jiggs bermudagrass for the first 28-30 days. It is recommended that a producer maintain adequate stocking rates if grazing cattle on a high producing hybrid such as Jiggs bermudagrass. If a producer would consider grazing Jiggs bermudagrass during the first 28 days of growth, he/she would see advantages in animal production. With high amounts of CP in immature Jiggs, there would be higher levels of protein entering the rumen causing higher amounts of microbial N, therefore increasing intake and at the same time increasing energy. Common, Russell, Tifton-9, and Pensacola are recommended if a producer is not an intensive forage manager. These results would be similar to the findings of these same cultivars if grown at different locations throughout Louisiana. Genetic potential of the forage and environmental effects contribute to the results when grown at different locations.

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Appendix: Supplementary Data

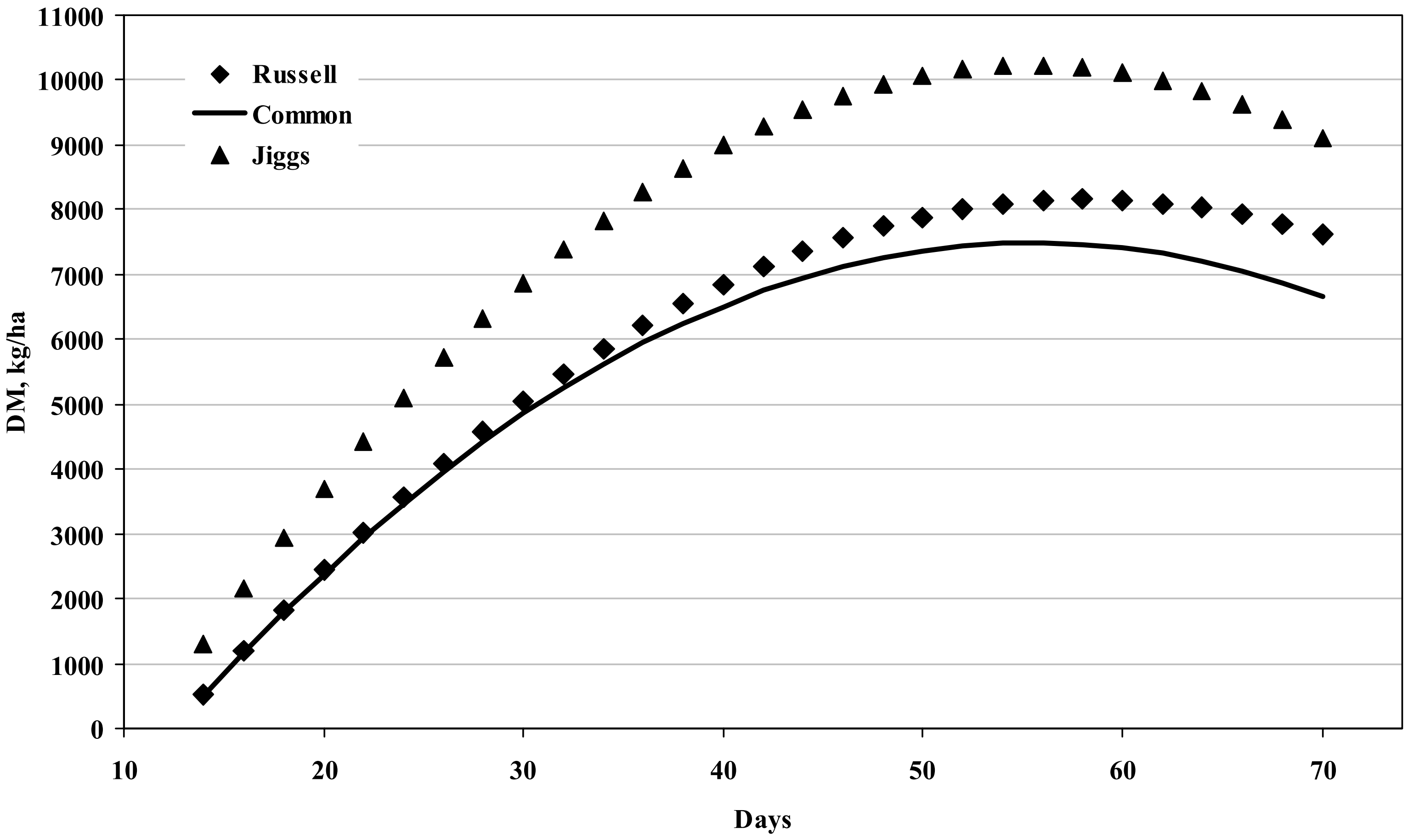

Figure 1. Predicted DM production of bermudagrass cultivars over different periods of growth

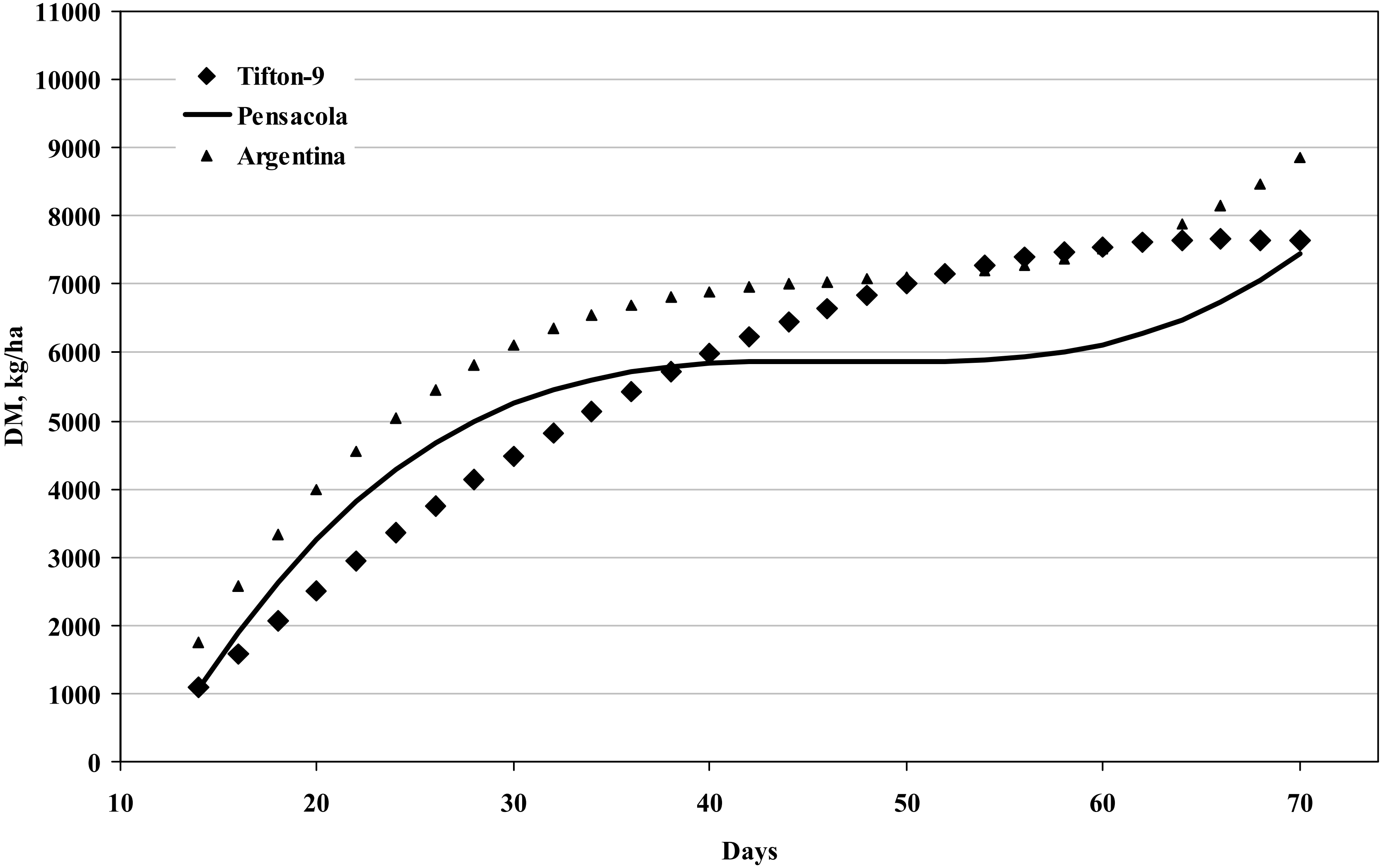

Figure 2. Predicted DM production of bahiagrass cultivars over different periods of growth

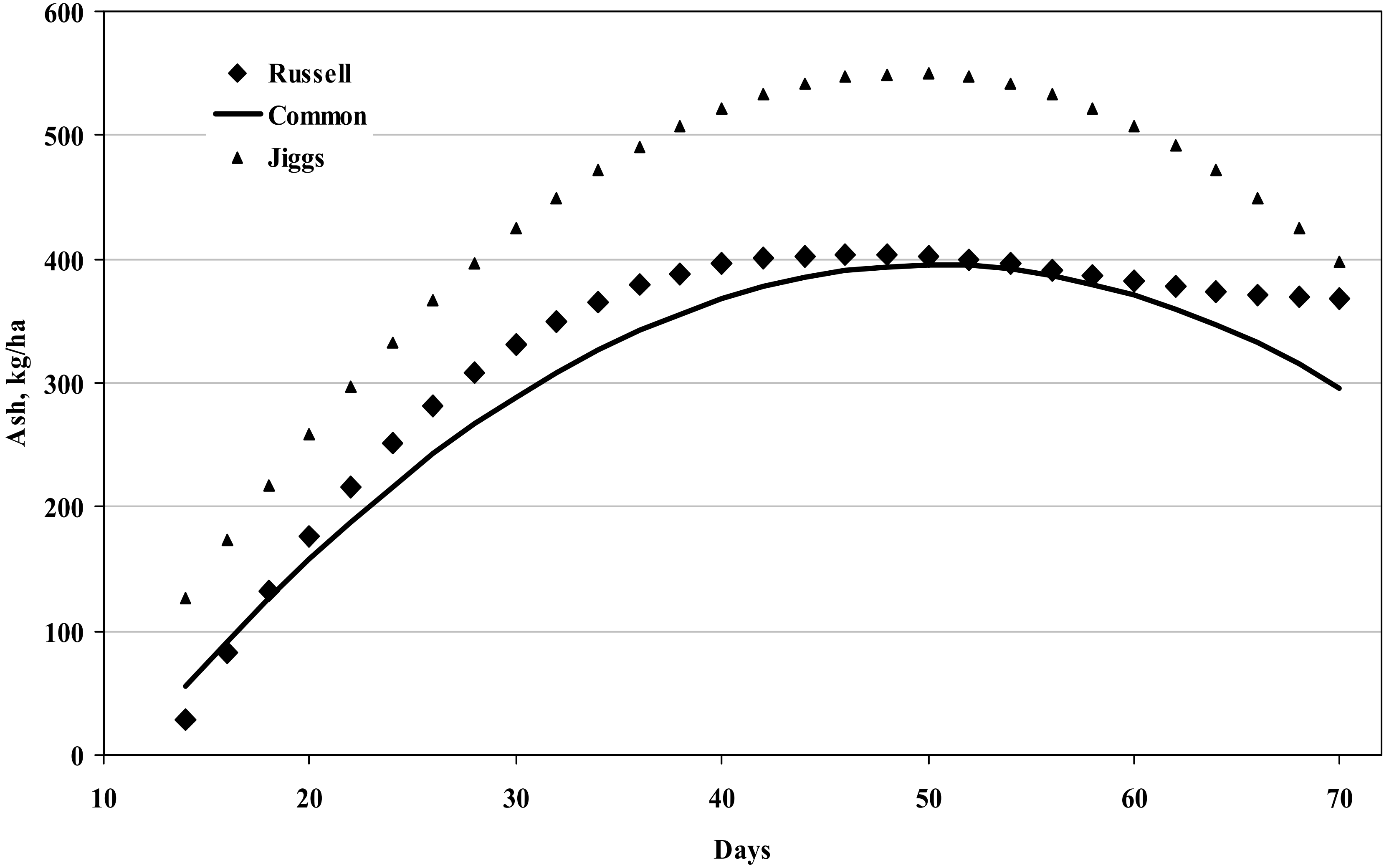

Figure 3. Predicted ash production of bermudagrass cultivars over different periods of growth

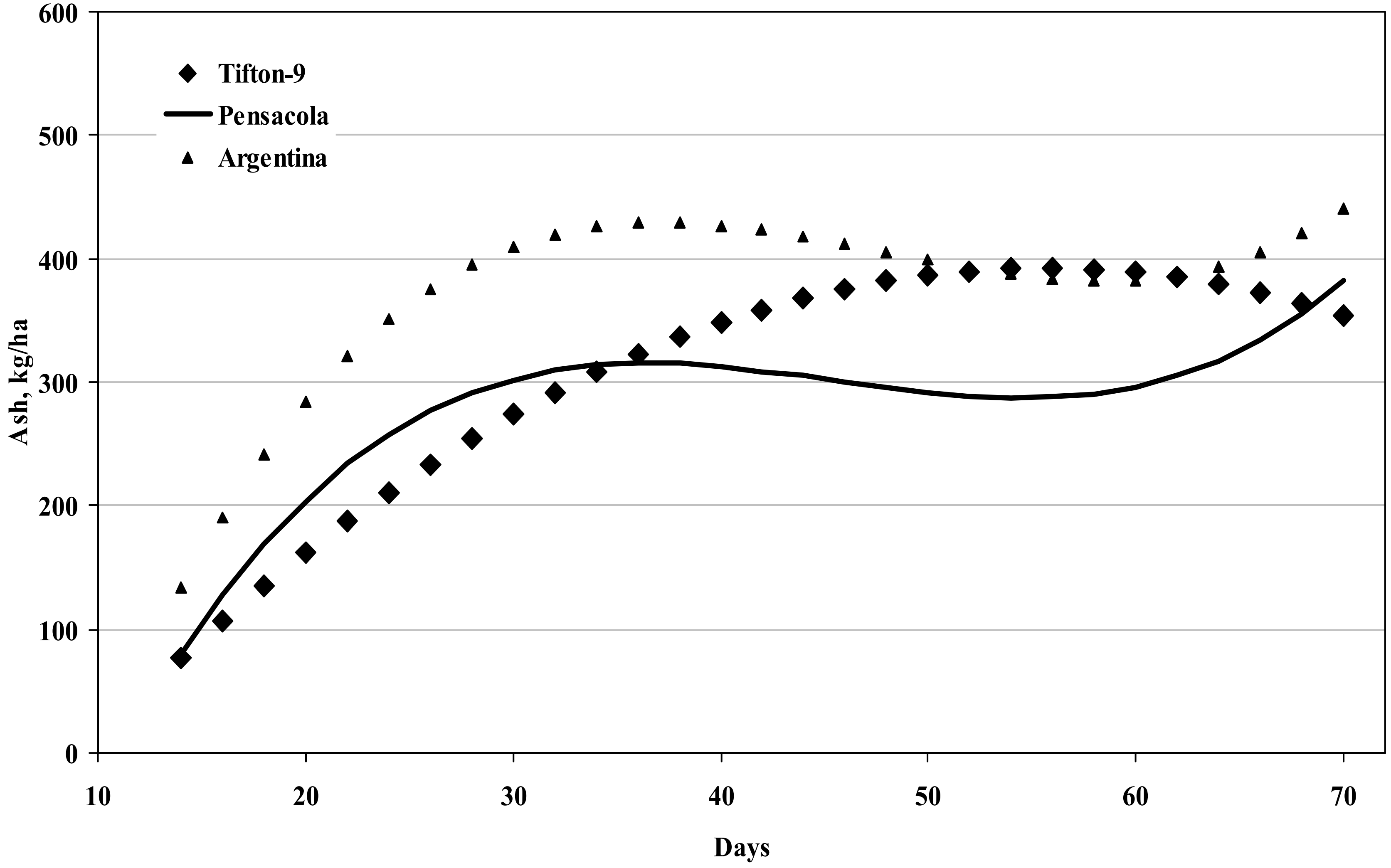

Figure 4. Predicted ash production of bahiagrass cultivars over different periods of growth

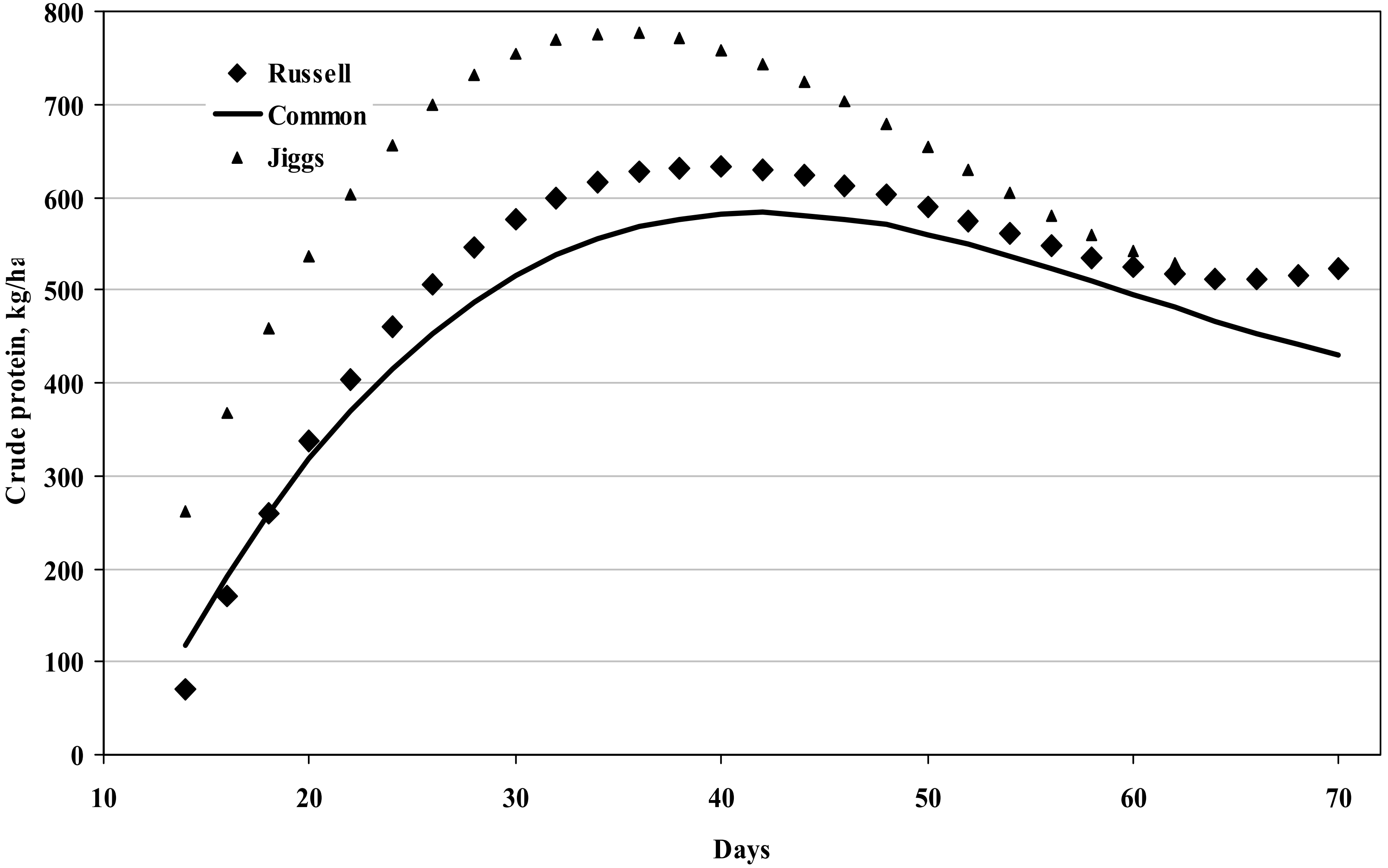

Figure 5. Predicted crude protein production of bermudagrass cultivars over different periods of growth

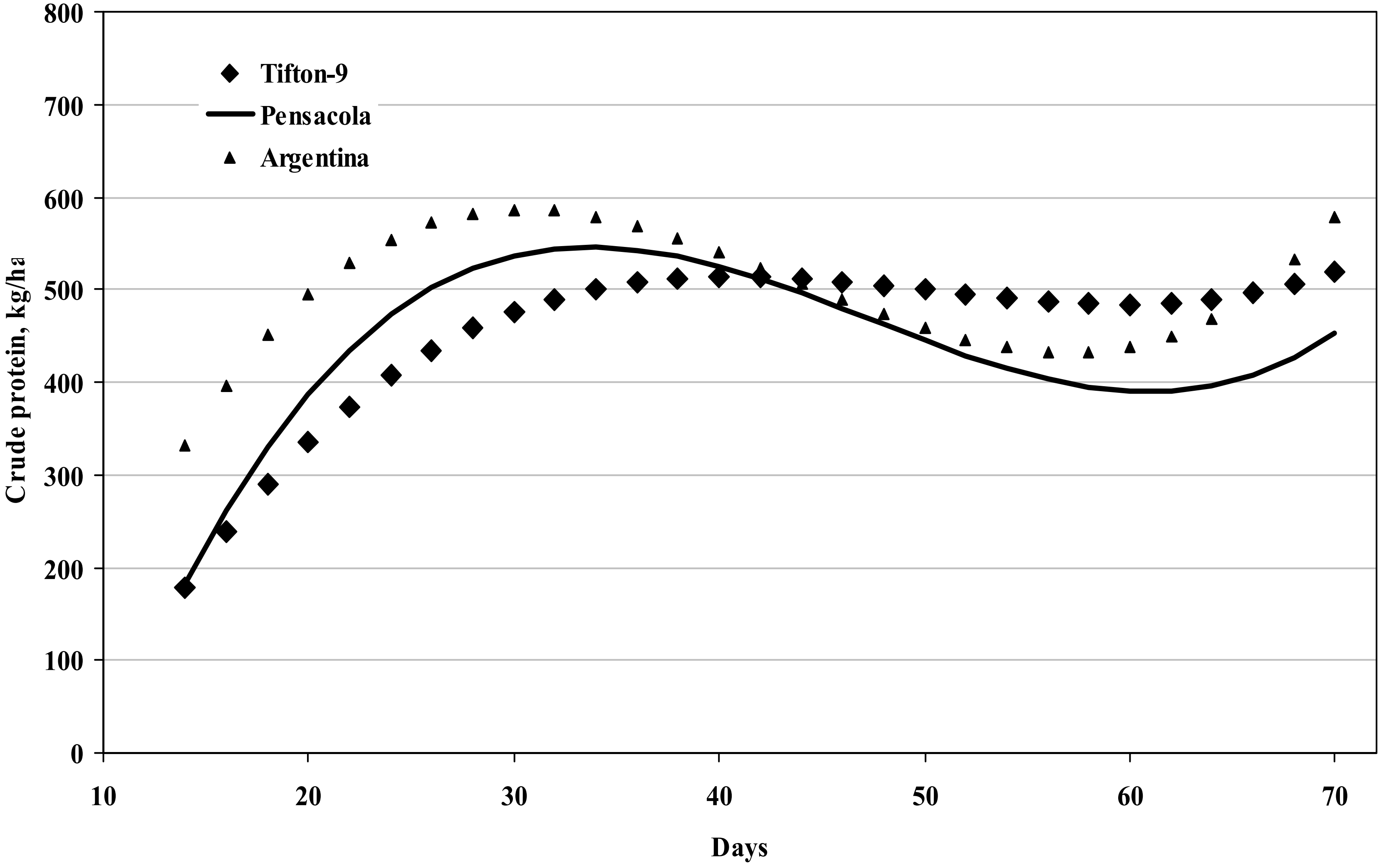

Figure 6. Predicted crude protein production of bahiagrass cultivars over different periods of growth

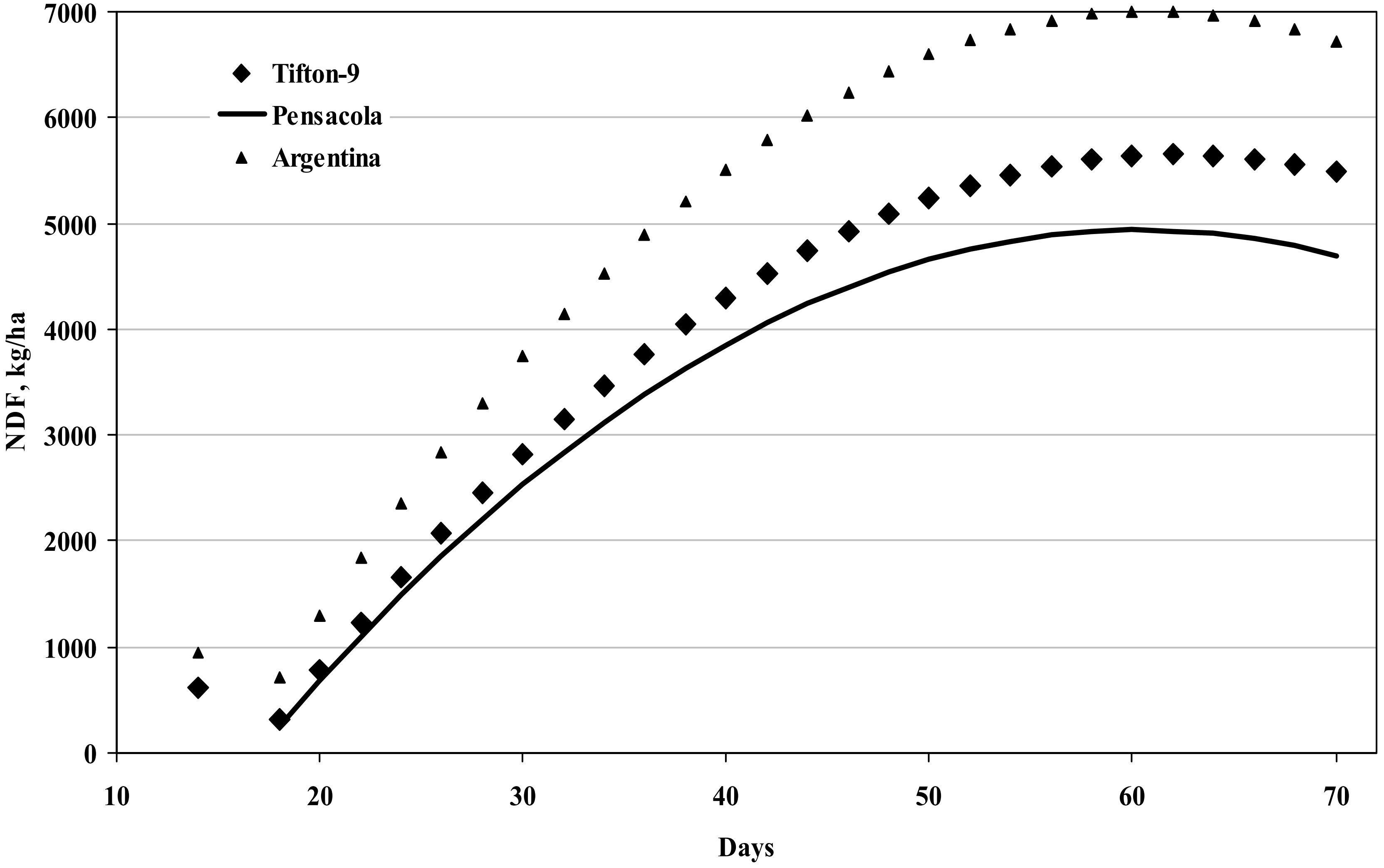

Figure 7. Predicted neutral detergent fiber production of bermudagrass cultivars over different periods of growth

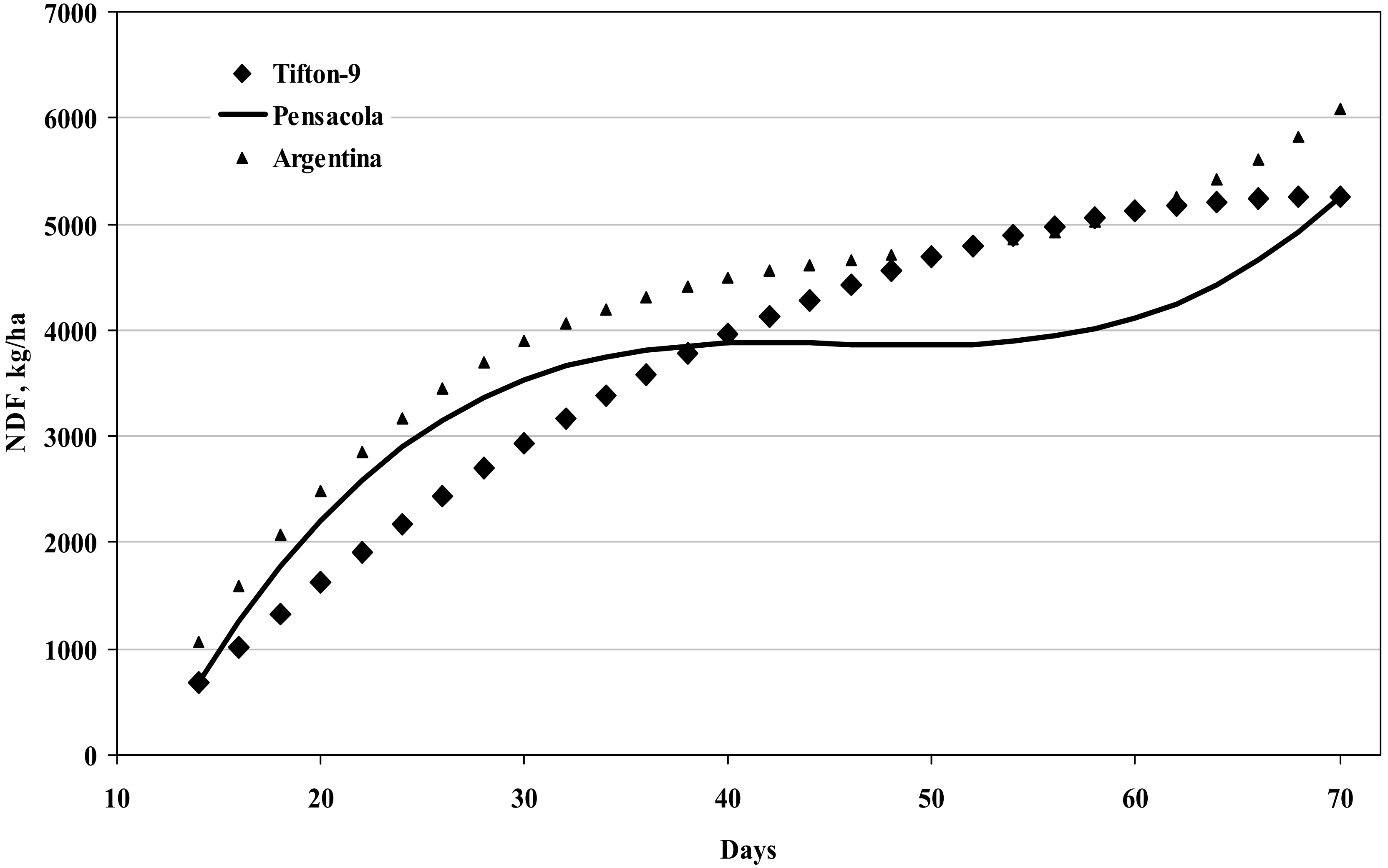

Figure 8. Predicted neutral detergent fiber production of bahiagrass cultivars over different periods of growth

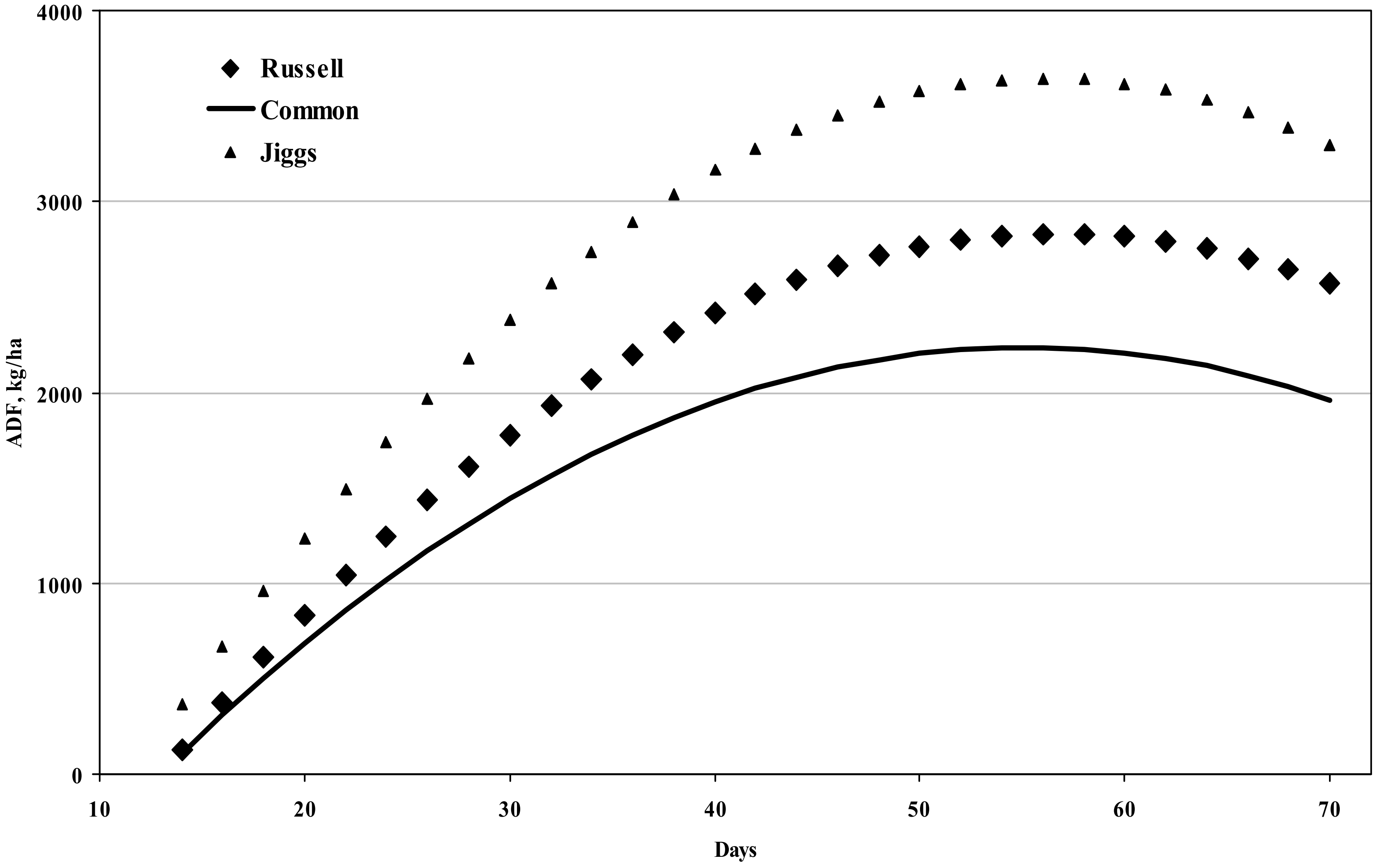

Figure 9. Predicted acid detergent fiber production of bermudagrass cultivars over different periods of growth

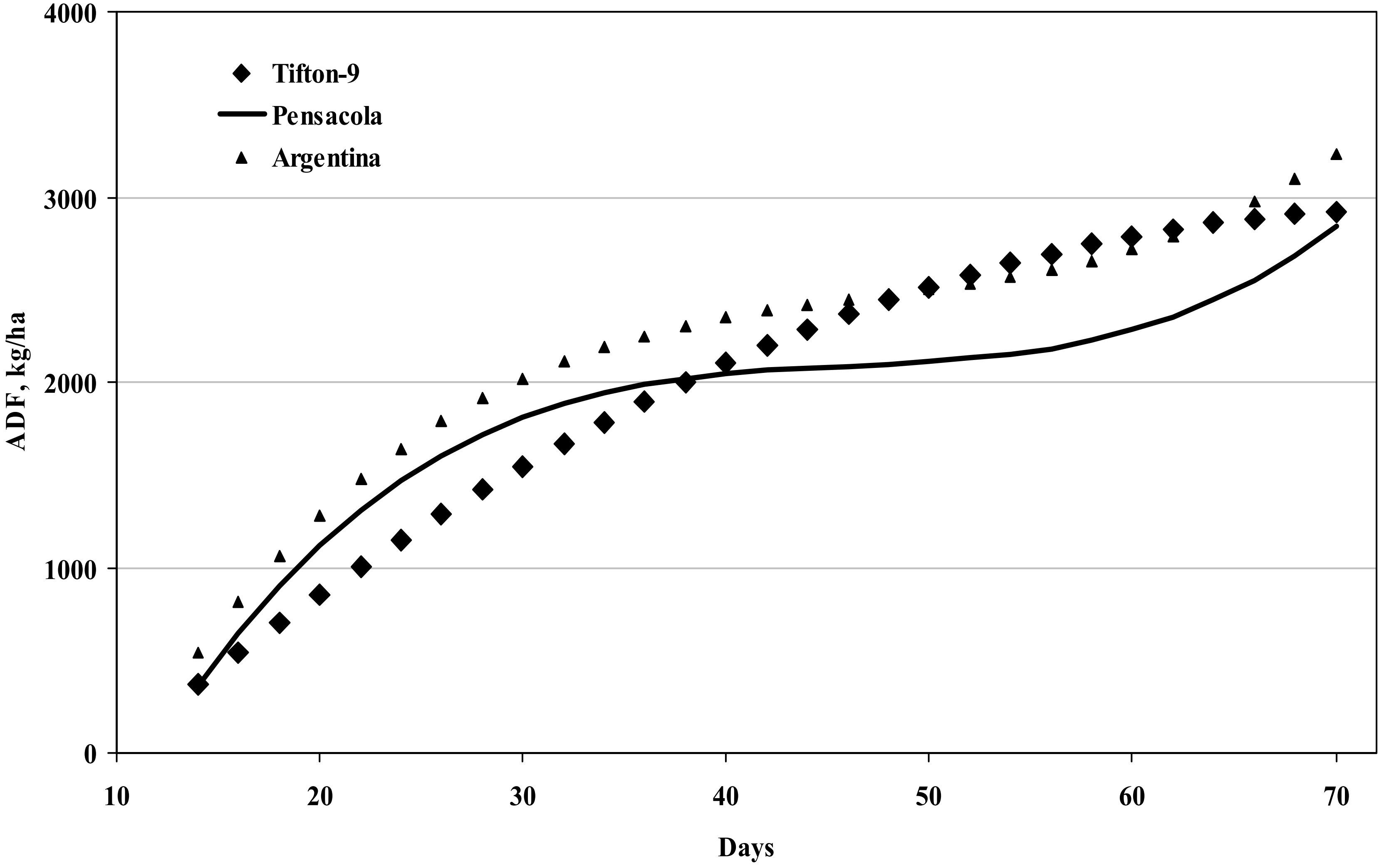

Figure 10. Predicted acid detergent fiber production of bahiagrass cultivars over different periods of growth

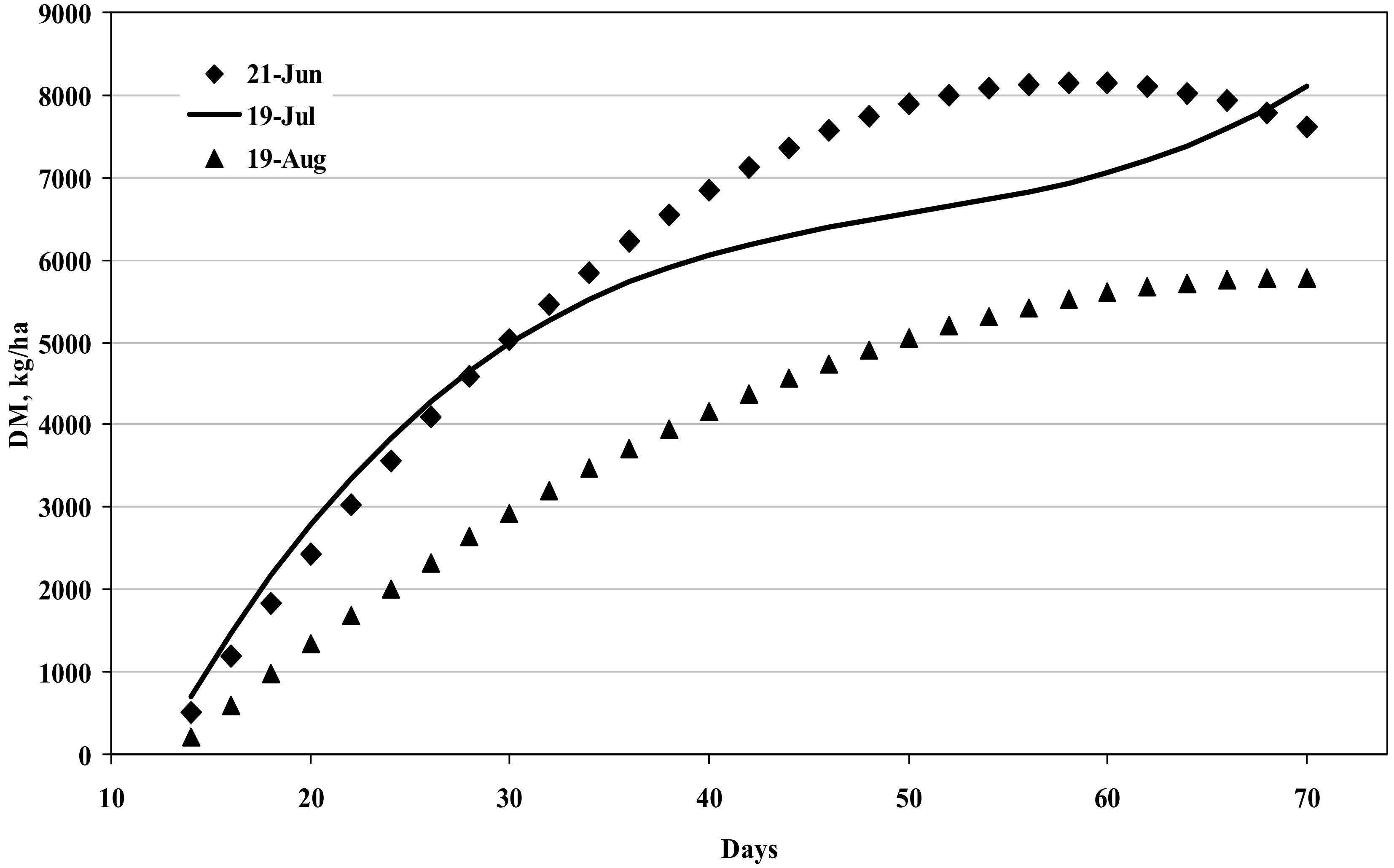

Figure 11. Predicted DM production of Russell bermudagrass cultivars over different periods of growth with different start dates.

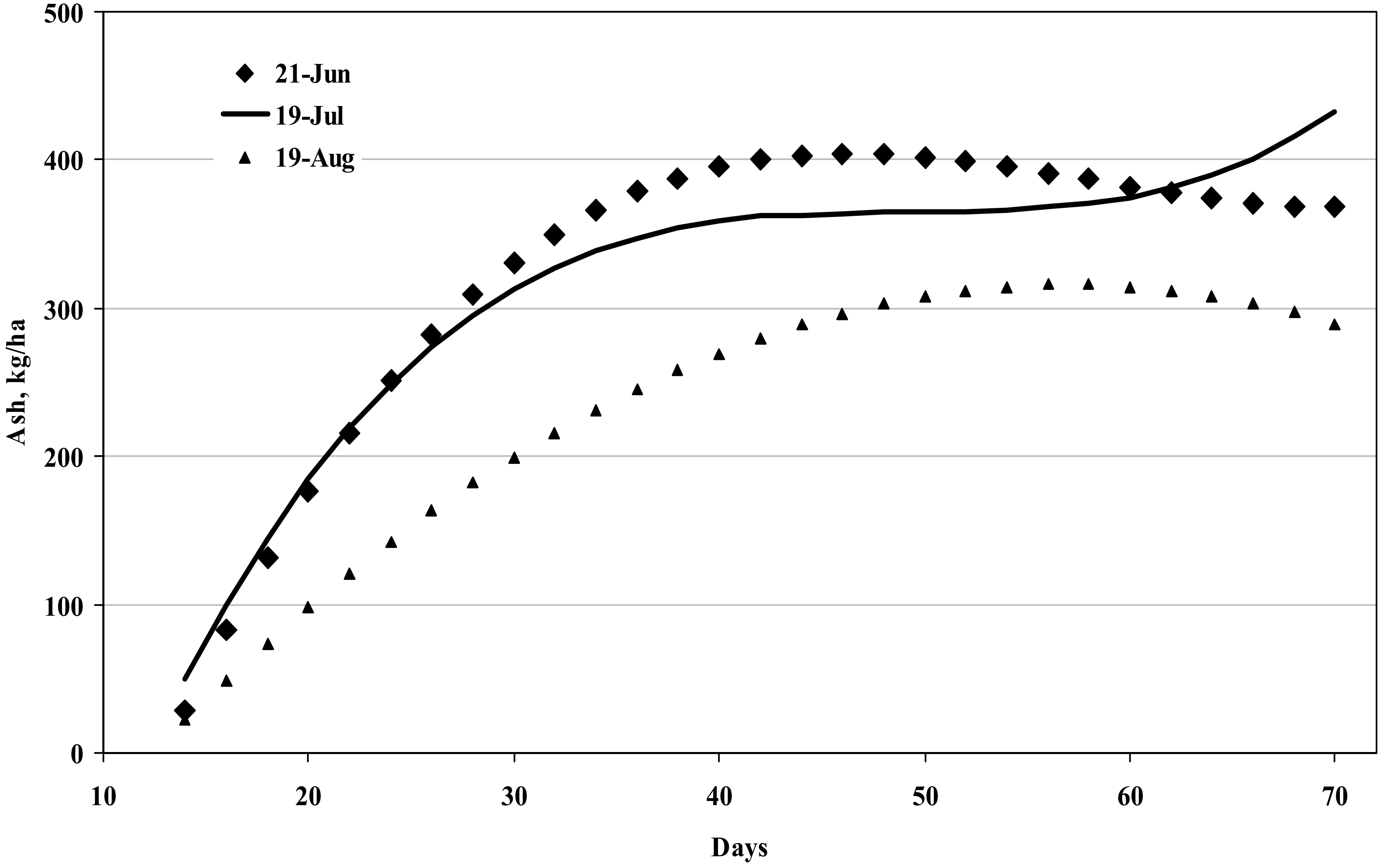

Figure 12. Predicted ash production of bermudagrass cultivars over different periods of growth with different start

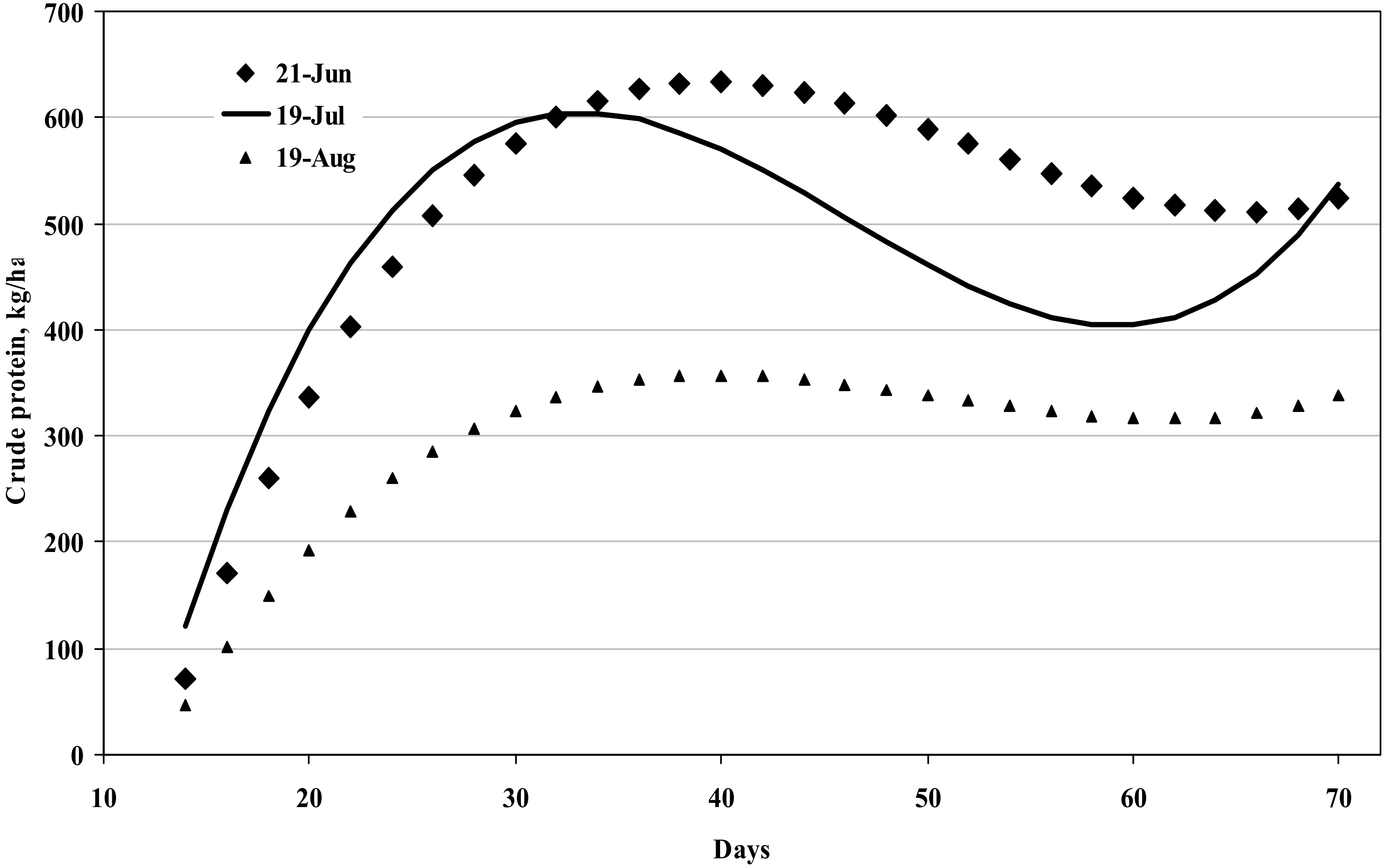

Figure 13. Predicted crude protein production of bermudagrass cultivars over different periods of growth with different start dates.

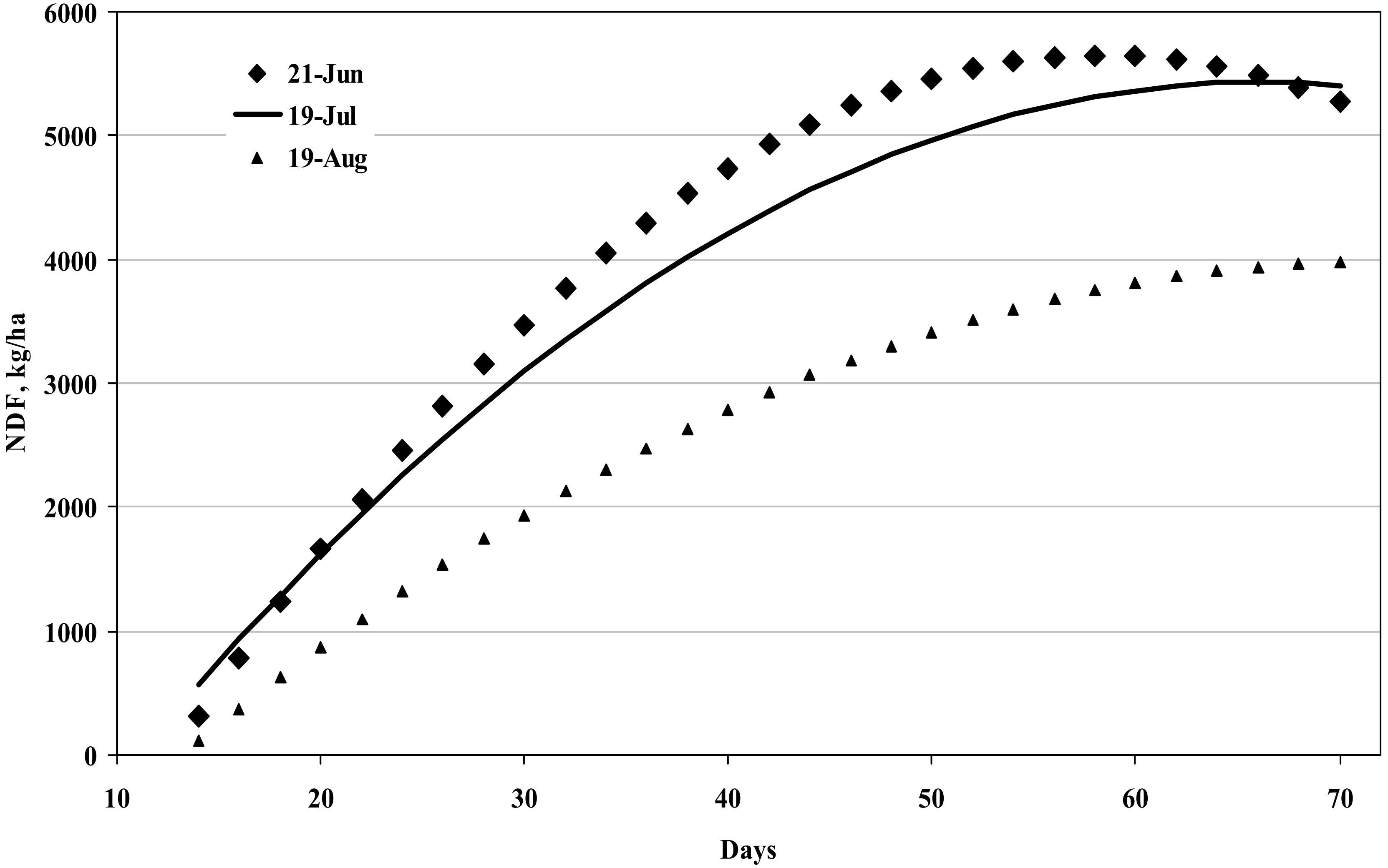

Figure 14. Predicted neutral detergent fiber production of bermudagrass cultivars over different periods of growth with different start dates.

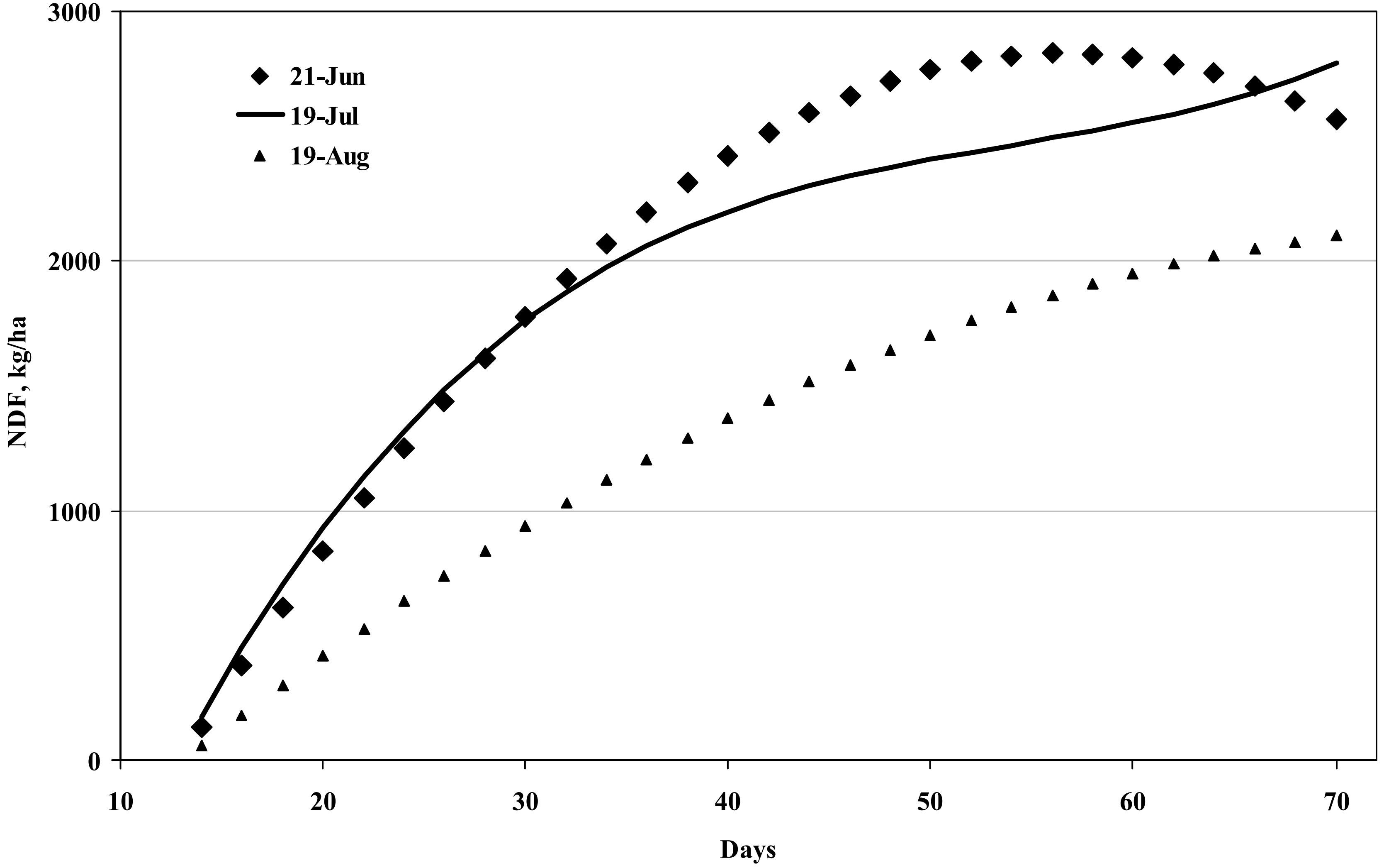

Figure 15. Predicted acid detergent fiber production of bermudagrass cultivars over different periods of growth with different start dates.

Vita

Ryan Dore' was born on August 29, 1978, in New Iberia, Louisiana. He is the son of Mark and Susan Dore'. He graduated from New Iberia Senior High in May of 1996 and then attended Louisiana State University at Baton Rouge for four years. In May of 2000, he received the Bachelor of Science degree in animal science. After graduation, he decided to further his education by entering graduate school. In the summer of 2000, he enrolled at Louisiana State University to pursue a Master of Science degree in the Animal Science Department with emphasis in ruminant nutrition.