GRAZING AND CUTTING MANAGEMENT OF ALAMO SWITCHGRASS IN ALABAMA

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VITA

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DISSERTATION ABSTRACT

GRAZING AND CUTTING MANAGEMENT OF ALAMO SWITCHGRASS IN ALABAMA

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Switchgrass has potential for beef cattle enterprises in Alabama, but few grazing studies have been conducted with it. 'Alamo' switchgrass is the highest-yielding variety of Alabama, but it has not been evaluated under grazing. Therefore, the objectives of this research were to determine the effect of: 1) defoliation intensity on morphology and biomass of Alamo; 2) timing of the first harvest on yield and quality of Alamo; and 3) stocking rate and stocking method on steer performance, pasture growth and forage quality.

A greenhouse study evaluated effects of 5-, 15- and 25-cm stubble heights on biomass production and morphology.

Results indicated that total yield and regrowth yield, stubble and below-ground biomass, leaf area, leaf-to-stem ratio, leaf number/tiller and stem length tended to increase ($P<0.05$) as stubble height increased.

A plot study (E.V. Smith Research Center) compared cutting intervals (3, 6 and 9 weeks) with early or late initial cuts in 1995 and 1996. Overall, the early-start and longer cutting intervals produced the highest seasonal dry matter (DM) yield, neutral detergent fiber (NDF) and acid detergent fiber (ADF) concentrations, but lower crude protein (CP) concentration.

In a grazing study at the Wiregrass Substation in 1995 and 1996, paddocks were stocked at 5.71, 7.61 and 9.51 steers ha^{-1} and grazed continuously (CS) or rotationally (RS). More forage was produced under RS than under CS (medium and high stocking rates (SR), both seasons). Forage present decreased as SR increased, except under RS in the first season where there was no change. Forage quality tended to be higher under CS than under RS, and at higher SR. Average daily gains (ADG) in the first season were similar for both methods and decreased slightly ($P<0.10$) as SR increased. In the second season, ADG differed ($P<0.05$) between methods and decreased as SR increased as early as day 56 of grazing.

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INTRODUCTION

Cow-calf enterprises in Alabama largely depend on bermudagrass (*Cynodon dactylon* L. Pers.) and bahiagrass (*Paspalum notatum* Flugge) for warm-season forage. Because these forages initiate growth late in spring and undergo dormancy early in fall, the grazing season is relatively short. Steer performance from these pastures has been poor (Hoveland, 1968; Hoveland *et al*., 1971). Cool-season annuals can be used to furnish complementary forage from late fall through mid-spring, but annuals are more expensive and troublesome to grow. As a perennial complement to the two predominant warm-season grasses, switchgrass (*Panicum virgatum* L.) appears to be promising for lengthening the grazing season because it has higher yields and a growing period that overlaps that of the existing forage base.

Switchgrass is a temperate, warm-season bunch grass that is native to North America. It is adapted to soils with pH values of 4.9-7.6 (Duke, 1978; Panciera and Jung, 1989), rainfall of 400-2600 mm yr^{-1} and average annual temperature of 7-26 °C (Panciera and Jung, 1989). In North America, switchgrass is a component of the tall-grass prairie

(Weaver, 1968). In South and Central Alabama, it is a component of the longleaf pine-bluestem range (Miller and Owsley, 1994). Potential uses of this grass include soil erosion control, reclamation of disturbed sites, nesting areas for upland birds and waterfowl, wildlife cover, permanent pasture (Panciera and Jung, 1989) and bioenergy (Sladden *et al.*, 1991). According to Anderson (1988), in Nebraska switchgrass starts growth late in spring and produces at least 60% of its growth between June 1 and August 31. Therefore, it can provide abundant forage for mid-summer grazing. In Alabama, growth of switchgrass starts as early as January-February, depending on the cultivar and season (Sladden and Bransby, 1992). Beaty *et al.* (1978) indicated that, in the Southeastern United States as a whole, growth of switchgrass starts in March.

Despite the potential that switchgrass presents from cutting experiment data, optimal management practices have not been developed, particularly under grazing. Although extrapolation of results from cutting experiments or from grazing experiments conducted with other grasses could give some indication of the potential of this grass for grazing, readily usable recommendations would not be possible. Even within the switchgrass species, there are cultivars and ecotypes of divergent morphology and adaptation, which are likely to respond to management practices differently. In addition, there are unsettled controversies regarding optimal stocking methods (rotational versus continuous) and optimal stocking rates, even with widely studied forages.

Proponents of the put-and-take method such as Mott (1960) have contended that an optimum stocking rate can be attained by changing the number of animals or by changing the pasture size, thus allowing for overcoming seasonal fluctuations in forage supply (Wheeler *et al.*, 1973). However, biological and economic analyses of stocking rate data result in different optima (Bransby, 1989; Hildreth and Riewe, 1963), so there cannot be a universal optimum stocking rate. Also, no grazing system has universal suitability to all forage types, climates, and management objectives (Wilson, 1986; Dwyer *et al.*, 1984, Martin and Whitfield, 1973). Recent developments in contract-grazing and pricing of cattle by weight class as is practiced in the United States (Bransby, 1996) challenge the contention that a universal optimum stocking rate exists. Booysen *et al.* (1975) recommended that for each grazing system an economic optimum stocking rate be determined. This will require that multiple grazing intensities be evaluated to simulate different production scenarios. Also, reasons other than economics may limit the producer's ability to choose a specific stocking method. According to Bransby (1988), it is desirable that at least three grazing intensities be used in grazing experiments so that an economically optimum stocking rate can be determined from derived functions, regardless of market changes.

Few studies have addressed cutting interval and timing of first cut effects on switchgrass forage production, and few grazing studies have been conducted with switchgrass. How stubble height affects morphology and dry matter partitioning of switchgrass also is poorly understood, and these could impact regrowth and persistence of switchgrass. Furthermore, because there is great genetic diversity within the species, it is likely that optimum management could vary among cultivars and ecotypes. Therefore, it is important to evaluate each cultivar separately.

OBJECTIVES

Since there is evidence that switchgrass has excellent potential to play a role in cattle production throughout the Southeast, the objectives of this research were:

1) to determine the effect of stubble height on morphology and dry matter partitioning of Alamo switchgrass in the greenhouse;
2) to examine the effects of timing of the first cut and cutting interval on total season yield, forage quality and yield distribution of Alamo switchgrass, when harvested for hay; and
3) to determine the effects of stocking rate and stocking method on steer performance, pasture growth, forage quality and morphology of Alamo switchgrass.

REVIEW OF LITERATURE

Establishment of switchgrass

One of the most difficult tasks in growing switchgrass is its establishment. Plant breeders have released various cultivars with different requirements for germination and for growth, particularly at seedling stages. Researchers have made efforts in the development of seed treatment techniques and cultural practices for switchgrass. However, when these techniques were tried, results from different seasons, locations and cultivars were not consistent. Therefore, there is still no universally standard cultural practice that can be recommended to producers. Difficult establishment is probably one of the reasons why switchgrass is not extensively grown in the Southeast, where old stands of bermudagrass and bahiagrass already exist.

Although optimal seeding rates of 2.4-4.8 kg pure live seed ha^{-1} have been recommended for switchgrass (Moser and Vogel, 1994), failure in establishment at these rates may still occur. The first challenge that was addressed is seed dormancy, which has been responsible for delayed germination. Early planting has been recommended for successful establishment in Pennsylvania (Panciera and Jung, 1989). Germination can be improved significantly if neoteric seed (1- to 18-month old) of switchgrass is prechilled for seven days at 5°C (Panciera *et al.*, 1985) or if it is scarified (Jensen and Boe, 1991; Sautter, 1962; Byers, 1973). Earlier, McWilliams (1950) had indicated that seed dormancy of switchgrass could be reduced with age of seed, so long-term storage may improve germination. Other recommendations include early to mid-spring planting (Vassey et al., 1985) or dormant planting in late fall (Moser and Vogel, 1994). In addition to establishment challenges posed by seed dormancy, Miller and Owsley (1994) reported an interaction between soil type and planting depth for seedling emergence.

Studies on the effects of tillage methods and use of chemicals on switchgrass establishment have yielded inconsistent results. In Nebraska, switchgrass was successfully established with roto-tilling and irrigation (Potvin, 1993) or with sod-seeding and application of atrazine [6-chloro-N-ethyl-N'-(1-methylethyl)-1,3,5, triazine-2,4, diamine] (Samson and Moser, 1982). Application of carbofuran, atrazine and paraquat (1,1'-dimethyl-4,4'-bipyridinium ion) has improved switchgrass establishment. Successful results were achieved by McKenna and Wolf (1987) with a no-till seeding which included phosphorus and carbofuran application, but Bryan *et al.* (1984) reported different results when they used carbofuran with sod-seeding. In other work, atrazine did not improve seedling establishment under conventional tillage (Bahler *et al.*, 1990).

Cutting Management

Effects of time, height and frequency/interval of cutting on forage plants have been determined for several species. In general, cutting frequently decreases DM yield while increasing forage quality because less mature tissue has lower fiber content, but optimal defoliation regimes can be as diverse as plant species or cultivars.

Beaty and Powell (1976) recorded 14.8 Mg ha^{-1} of DM from switchgrass with one harvest, but reported reduction in yield, clone survival and tillers per clone for two cuts per year. Balasko *et al.* (1984) found that yield of 'Blackwell' switchgrass from two cuttings was higher than the yield from one or three cuttings, and that two cuttings resulted in better yields if the second cutting was taken before frost occurred. Lower yields under one cutting system were attributed to lodging. Based on results from that study, they recommended that grazing on extensively grown switchgrass be initiated near boot stage and be managed to leave a 15-18 cm stubble height. However, results from small-plot cutting experiments are seldom reproducible under large-scale production or under grazing. Moser and Vogel (1994) also recommended that grazing be initiated when plants are about 30 cm tall. Haferkamp and Copeland (1984) obtained more vigorous plants and the highest forage yield from Alamo switchgrass by applying 45-45-45 kg ha^{-1} of N, P and K fertilizer in spring and mowing it in mid-summer, but forage quality was lower than when harvests were made in spring or early-summer. Brejda *et al.* (1994) reported that forage yields of switchgrass increased for late-May and mid-June harvests in Missouri.

Clavero (1993) worked with Alamo switchgrass in Texas and reported a higher growth rate, leaf area index and light interception when cutting at 30-cm stubble height every 42 days. Turner *et al.* (1993) found that in a tallgrass prairie containing switchgrass, above-ground production was highest with six cuttings per year and with a 10-cm stubble height. In the same study, live grass root biomass was less in plots mowed in two previous years than on same-treatment plots left unmowed during that time. Gillen and McNew (1987) reported that both maximum growth rates and maximum regrowth attained following a single mowing of switchgrass declined as the time of cutting was extended into the growing season.

According to Trocsanyi (1991), cutting at 20-cm stubble height decreased the yield of the first cutting in the second growing season, and plots not cut in the first growing season gave better yields in the second season than previously cut plots. Cutting at 30 cm produced better regrowth than cutting at 20 cm. Regrowth yields decreased as date of first cutting was delayed. George and Obermann (1989) attributed the delay of the major supply of herbage of switchgrass to partial spring defoliation, and no serious reduction in switchgrass quality was observed. They found that 6-week regrowth of a 1 June cutting accounted for 75-85% of total season DM and *in vitro* digestible DM yields. However, switchgrass appears to produce its only crop of tillers in spring, and early removal can seriously reduce herbage production (Hyder, 1974).

Pretorious *et al.* (1974) found that clipping height of 'Sabi-Panicum' (*Panicum maximum* Jacq), a relative of switchgrass, affected regrowth more than the clipping frequency. They also found that defoliation to a height of 16 cm at 4- to 6-weekly intervals appeared to be more satisfactory in terms of shoot DM yield and root production. In this study, branching of 'Sabi-Panicum' occurred at the first three node positions below clipping height. Sims *et al.* (1971) found that defoliating switchgrass plants prior to June 26 induced rhizomes to produce aerial shoots before the end of the growing season. Aerial shoots are less likely to be a desirable trait. They often present a stunted growth, so they could be competing with basal tillers for photosynthates. Basal tillers are the perenniating organs of grass clones.

According to Harrison and Hodgson (1939), yield was similar at the 3- or 6-cm stubble heights in tetraploid 'westerwolds' ryegrass (*Lolium multiflorum* Lam.), perennial ryegrass (*Lolium perene* L.) and prairiegrass (*Bromus willdenowii* Kunth). Regrowth at the end of the experiment was highly correlated with total stubble and root weights (r=0.84).

Grazing Management

Switchgrass is known to be highly diverse with regard to morphology. According to Moser and Vogel (1994), switchgrasses have been divided into lowland and upland types. Lowland types are taller, coarser, and generally more rust-resistant. They have a more bunch-type growth, and they may be more rapid-growing than upland types. Wild lowland types are found on flood plains, while upland types are found in plains that are not subject to flooding.

Alamo switchgrass (a lowland type) was released by the United States Department of Agriculture, Soil Conservation Service and the Texas Agricultural Experiment Station in 1979 as a commercial variety for use in pasture and range seeding (Anonymous, 1979). Promising features (early growth, early seed production, and high forage yield) were identified in the initial evaluations that followed the collection of the first plant material from the north bank of the Frio River, in Texas by E. McEntire in 1964 (Allen, 1978). Yields from cutting trials in Alabama when Alamo was managed as an energy crop (Sladden and Bransby, 1992; Maposse *et al.*, 1995a; Miller and Owsley, 1995) were consistently higher compared to seven other cultivars. Growth of Alamo can start as early as January in Alabama (Sladden and Bransby, 1992), but few studies (for example, Maposse *et al.*, 1995b) have examined its performance under grazing. 'Kanlow' switchgrass (another lowland ecotype) gave season-long ADG as high as 0.96 kg in North Carolina, in a study in which put-and-take stocking was used (Burns *et al.*, 1984).

The few studies that have been conducted with switchgrass for forage used upland types. Management practices outlined by Moser and Vogel (1994) are generalized and probably disregard cultivar differences. In the field of plant breeding, significant work has been directed at improved forage quality of switchgrass. One example was the selection of 'Trailblazer' switchgrass for its higher *in vitro* dry matter digestibility (IVDMD) (472-637 g kg^{-1}) in preference to 'Pathfinder' switchgrass (436-620 g kg^{-1}) (Ward *et al.*, 1986). In terms of animal performance this digestibility difference has translated to ADG advantage, amounting to 0.09-0.18 kg gain day^{-1} (Ward *et al.*, 1986; Vogel *et al.*, 1991).

Stocking rate and stocking methods

The linear relationship between ADG and stocking rate within the range of economically feasible stocking rates has been conclusively established. A detailed review of models explaining this relationship was reported by Sandland and Jones (1975).

Despite claims that rotational stocking increases animal product per unit area compared to continuous stocking (Blaser *et al.*, 1973; Ernst *et al.*, 1980; McMeekan and Walshe, 1963), many experiments have not successfully separated the effects of plant and animal species, environment, stocking rate, stocking method, season and time of grazing from differences caused by stocking method. Smith *et al.* (1986) reported a seasonal change in response to stocking method: at a number of stocking rates, sheep grazing annual ryegrass (*Lolium multiflorum* L.) gained better in fall and winter under rotational stocking than under continuous stocking, while in spring this trend was reversed. Bransby (1993) found that, on Coastcross II bermudagrass, ADG at equal levels of available forage was higher for continuous stocking than for rotational stocking in some cases, but there were no differences in other cases. The author also reported no differences in ADG between continuous and rotational stocking on kikuyugrass (*Pennisetum clandestinum* Hochst. ex Chiov).

Numerous studies have used lighter stocking rates for continuous stocking and heavier stocking rates for rotational stocking (for example, McKown *et al.*, 1991; Pitts and Bryant, 1987). Even supporters of the Voisin method of rotational stocking such as Murphy(1987) and Savory (1983) have failed to measure forage availability in comparisons between rotational and continuous stocking, so many claims in favor of rotational stocking are not supported by properly designed and properly conducted experiments.

Factors like drought often affect treatment expression in grazing experiments, since these factors affect forage availability. According to Kee *et al.* (1991), response to stocking method on bermudagrass was only evident in seasons in which rainfall was above normal. Barnes and Franklin (1974) also found that, during the dry season, stocking rate was the only treatment to affect animal performance, with better weight gains from low stocking rate. There was no effect of stocking method on animal production. Clearly, data in the literature suggest that stocking rate is probably the most important single factor in grazing management.

Interactions between stocking rate and stocking method may offer producers alternatives to use either rotational or continuous stocking at the best stocking rate as dictated by logistics of the whole enterprise. O'Sullivan (1984) obtained a 33% increase in animal production at a high stocking rate and only 7.6% increase at low stocking rate on perennial ryegrass in Holland by using rotational stocking instead of continuous stocking. These results revealed a stocking rate x stocking method interaction. Complex interactions were found on bermudagrass (Kee et al., 1991) and on bahiagrass (Kee *et al.*, 1993): the advantage of one method of stocking over another was affected by stocking rate and by year. Zimbabwean researchers reported declines in average daily gain at similar rates (Clatworthy and Muyotcha, 1983) for continuous and rotational stocking as stocking rate increased, but gains were higher under continuous stocking. Under rangeland conditions in Wyoming, Hart *et al.* (1988) found that weight gain decreased with grazing pressure, but was not affected by stocking method.

There seems to be agreement among researchers that rotational stocking often increases carrying capacity, but the recommended number of paddocks to be used and the resulting animal performance are still a subject of controversy. Bransby (1988) obtained higher carrying capacity on bermudagrass, rhodesgrass (*Chloris gayana* Kunth) and kikuyugrass for rotational stocking (using only six paddocks) than for continuous stocking, but gain ha^{-1} was similar. McMeekan and Walshe (1963) reported that, at optimum stocking rate, rotational stocking carried 5-10% more animals than continuous stocking. Emmick *et al.* (1990) found, on a hillside pasture in New York, that weight gains ha^{-1} of steers were not affected by grazing system, but rotational stocking increased the carrying capacity, particularly with a higher number of paddocks (12 or 16). From simulation models, Senft and Tharel (1989) also predicted a higher optimum stocking rate (carrying capacity) for rotational stocking, and indicated that rotational stocking with more than eight paddocks resulted in more beef produced per unit area than continuous stocking. These results are partly in disagreement with simulation by workers in South Africa (Booysen *et al.*, 1974) and actual experiments in Zimbabwe (Barnes and Denny, 1991). These researchers concluded that, above eight paddocks, there is little increase in periods of rest, so it would not be economically viable to make any further subdivisions of the pasture. The workers in Zimbabwe found that under rangeland conditions, continuous stocking at 0.56 steers ha^{-1} gave 13% better liveweight gains than rotational stocking with five or with eight paddocks, but they reported no differences at 0.40 steers ha^{-1}. According to Barnes and Franklin (1974), rest periods and number of paddocks had no effect on animal performance.

Pitts and Bryant (1987) reported similar gains for year-long continuous stocking and for short-duration grazing (a form of rotational stocking) with 16 paddocks at 0.08 animal units ha^{-1} in the first year, but confounded the treatments in the subsequent years by increasing the stocking rate on short duration grazing only. Mooso *et al.* (1989), working with 'Marshall' ryegrass and 'Dixie' crimson clover (*Trifolium incarnatum* L.) reported similar ADG for continuous and rotational stocking, but claimed higher economic net returns for rotational stocking. However, this apparent economic advantage resulted from using higher stocking rates on rotationally stocked paddocks and, since

ADG did not differ, there is a suggestion that pastures were understocked. The reported stocking rates were treated as a response variable. Unless forage availability is reported in grazing studies, using stocking rate as a response variable is questionable. The reason for this is because stocking rate is not a random variable, but rather a variable that is dependent on the reseacher's discretion, thus leaving room for subjectivity.

Periods of rest and grazing are the cornerstones of rotational stocking and are affected largely by number of subdivisions. Effects of these periods, however, are often confounded in grazing studies. Barnes and Franklin (1974) reported lower ADG of steers for 20-day periods of stay than for 5- and for 10-day periods of stay in 4-paddock units, and in general they obtained lower weight gains from 8- than from 4-paddock procedures. They also reported that gains per steer were generally lower at the high stocking rate than at the low stocking rate, but where stocking procedures involved 5- and 10-day periods of stay in 4-paddock units, gains per steer were actually higher at the high stocking rate.

Jung *et al.* (1985) found that, at a stocking rate of 2.9 heifers ha^{-1}, ADG was 0.48 and 0.47 kg for continuous and for rotational stocking, respectively, from a smooth bromegrass (*Bromus inermis* Leyss) pasture. Forage availability and quality did not differ between stocking methods. Hart *et al.* (1986) also reported similar performance for steers under continuous and rotational stocking. These results agree with Sharrow and Krueger (1979), who found that in experiments where stocking rates were equal for both continuous and short-duration grazing, animal gains were equal. Lehnert (1985) pointed out that improving other management factors is often more important than using rotational stocking to improve production from grazing systems.

McKown *et al.* (1991) obtained similar organic matter and metabolizable energy intakes by cattle with 14- or 42-paddock rotational stocking schemes on rangeland in Texas, suggesting that stocking density between these two levels of subdivision is relatively unimportant in rotational stocking. Forage crude protein intake, however, was higher on the 42-paddock system. In a 2-year study from Florida, Mathews *et al.* (1994) compared continuous stocking, and rotational stocking with fifteen or with three paddocks, and found no differences in ADG of heifers, but predicted a better long-term response for rotational stocking as a result of better stand longevity.

Bertelsen *et al.* (1993) used put-and-take stocking to compare continuous, 6-paddock rotational stocking and 11-paddock rotational stocking. They deliberately stocked the rotationally stocked pastures at a higher level than continuously stocked pastures, and reported 40% and 34% more liveweight gains for 6- and 11-paddock rotational stocking, respectively, over continuous stocking.

In comparisons between continuous and rotational stocking on rangeland, pasture size may have more effect on cattle performance than movement of livestock, due to the distance that animals have to travel for water and the resulting animal distribution. Pasture utilization declined as distance to water increased on larger pastures in Wyoming (Hart *et al.*, 1993). Vallentine (1990) established that animals should preferably not travel more than 0.8 km daily for water. Cows on continuously stocked small pastures spend a smaller percentage of time grazing and more time resting than cows on continuously stocked large pastures, or rotationally stocked pastures (Hart *et al.*, 1993). Better ADG were obtained with cows and calves on continuously stocked small pastures or rotationally stocked pastures than on continuously stocked large pastures, but heifers and dry cows were less sensitive to grazing method or pasture size (Hart *et al.*, 1993). Hepworth *et al.* (1991) found that steers at heavy stocking rates grazed longer under continuous than under rotational stocking. This is supported by O'Sullivan (1984) who found that cattle had 44% more grazing energy expenditure on continuous than on rotational stocking, because the former spent more time walking. Nevertheless, walking could be minimized even with continuous stocking if pastures were subdivided and the number of herds equaled the number of subdivisions. It is apparent from the literature that comparisons between continuous and rotational stocking have, in addition to confounding stocking rate with stocking methods, often been flawed by assuming that better production could be associated only with physical movement of livestock.

One of the major challenges in managing switchgrass under grazing is minimizing leaf selection, which appears to be the main reason for poor regrowth. Krueger and Curtis (1979) reported that yearling steers selected the leaves and the top parts of switchgrass plants. This was confirmed by Fisher *et al*. (1985) who reported that steers selected leaf material even in swards with 50% of dry matter partitioned as stems. With Alamo switchgrass such stem percentage would be observed in late-spring and early-summer (Bransby, personal communication). In decreasing order of preference, animals select young leaves and stems, older green leaves, green stems, dry leaves and dry stems (Wallace, 1984). Maposse *et al.* (1995b) also noted that, late in the grazing season, switchgrass paddocks that had been continuously grazed in summer exhibited senescent stems. In addition, regrowth occurred mainly as an abundance of aerial tillers, rather than basal tillers, and fewer leaves compared to that of forage in adjacent hay plots. On a tallgrass prairie, Jensen *et al.* (1989) stated that grazing animals generally removed the top canopy of forage first, particularly in dense swards, even though the highest quality feed in some cases may be at the base of the standing crop (Kothmann, 1984), with tillers being moderately defoliated the first time and severely defoliated afterwards. Sollenberger *et al.* (1988) and Maposse *et al.* (1995b) proposed close defoliation by means of rotational stocking as a way of controlling the accumulation of stem material and enhancing basal tiller recruitment. George and Reigh (1987) also indicated that rotational stocking was a suitable method for managing switchgrass. These concepts need to be evaluated in properly designed grazing experiments.

REFERENCES

Allen, D.D. 1978. Alamo switchgrass holds promise for South Texas pastureland. Cattleman. 65:121-122.

Anderson, B. 1988. Sequential grazing of cool-warm-cool season perennial grasses. The concept and practice. p. 274-279. *In* Proc. of the For. and Grassl. Conf. Baton Rouge, Louisiana, April 11-14, 1988.

Anonymous. 1979. Alamo switchgrass. Texas Agric. Exp. Sta. L-1774.

A.O.A.C. 1990. Official methods of Analysis of the Association of Official Analytical Chemists. 15th ed. A.O.A.C., Washington, D.C.

Bahler, C.C., L.E. Moser, T.S. Griffin, and K.P. Vogel. 1990. Warm-season grass establishment as affected by postplanting atrazine application. J. Range Manage. 43:421-424.

Balasko, J.A., D.M. Burner and W.V. Thayne. 1984. Yield and quality of switchgrass grown without soil amendments. Agron. J. 76:204-208.

Barnes, D.L. and R.P. Denny. 1991. A comparison of continuous and rotational grazing on veld at two stocking rates. J. the Grassl. Soc. Sth. Afr. 8:168-173.

Barnes, D.L. and M.F. Franklin. 1974. Some effects of varying the duration, frequency and intensity of grazing on the growth of steers on veld. Proc. Grassl. Soc. Sth. Afr. 9:133-137.

Beaty, E.R., and J.D. Powell. 1976. Response of switchgrass, *Panicum virgatum*, L., to clipping frequency. J. Range Manage. 29:132-135.

Beaty, E.R., J.L. Engel and J.D. Powell. 1978. Tiller development and growth in switchgrass. J. Range Manage. 31:361-365.

Bertelsen, B.S., D.B. Faulkner, D.D. Buskirk and J.W. Castree. 1993. Beef cattle performance and forage characteristics of continuous, 6-paddock and 11-paddock grazing systems. J. Anim. Sci. 71:1381-1389.

Blaser, R.E., D.D. Wolf, and H.T. Bryant. 1973. Systems of grazing management. p. 585-595. *In* M.E. Heath, D.S. Metcalfe, and R.E. Barnes (eds.). Forages. Iowa State Univ. Press, Ames, IA.

Booysen, P. de V., J.R. Clug and B.S. York. 1974. Number of camps for rotational grazing of veld. Proc. Grassl. Soc. Sth. Afr. 9:145-148.

Booysen, P. de V., N.M. Tainton and B.D. Foran. 1975. An economic solution to the grazing management dilemma. Proc. Grassl. Soc. Sth. Afr. 10:77-83.

Bransby, D.I. 1988. Rotational and continuous grazing interactions with stocking rate on warm season perennial pastures. p. 97-101. Proc. of the For. and Grassl. Conf. Baton Rouge, Louisiana, April 11-14, 1988.

Bransby, D.I. 1989. Justification for grazing intensity experiments: economic analysis. J. Range Manage. 42:425-430.

Bransby, D.I. 1993. Effects of grazing management practices on parasite load and weight gain of beef cattle. Vet. Parasitology. 46:215-221.

Bransby, D.I. 1996. Economic vs. biological optimum stocking rates for beef steers: some alternative perspectives. p. 156. *In* Agronomy Abstracts, ASA, Madison, Wisconsin.

Brejda, J.J., J.R. Brown, G.W. Wyman, and W.K. Schumacher. 1994. Management of switchgrass for forage and seed production. J. Range Manage. 47:22-27.

Bryan, W.B., T.A. Mills, and J.A. Cronaeur. 1984. Sod-seeding switchgrass and tall fescue into hill land pasture. J. Soil and Water Conserv. 39:70-72.

Burns, J.C., R.D. Mochrie, and D.H. Timothy. 1984. Steer performance from two perennial Pennisetum species, Switchgrass, and Fescue-Coastal Bermudagrass system. Agron. J. 76:795-800.

Byers, K.L. 1973. Evaluation of methods of reducing seed dormancy in switchgrass, indiangrass and big bluestem. M.S. Thesis, South Dakota State Univ., Brookings.

Clatworthy, J.N. and M.J. Muyotcha. 1983. Effect of stocking rate and grazing procedure on animal production and botanical composition of a Silverleaf desmodium/stargrass pasture. An. Rep. 1980-1981. Division of Livestock and Pastures, Zimbabwe. 171-173. Harare, Zimbabwe, Dept. of Res. and Specialist Services.

Clavero, C.T. 1993. Effect of defoliation on growth, leaf area index and light interception in tropical grasses. Revista de la Facultad de Agronomia, Univ. del Zula. 10:57-67.

Duke, J.A. 1978. The quest for tolerant germplasm. In J.A. Jung (ed.). Crop tolerance to suboptimal land conditions. Spec. Publ. 32. Madison, Wis.: American Society of Agronomy, 1-61.

Dwyer, D.D., J.C. Buckhouse, W.S. Huey. 1984. Impacts of grazing intensity and specialized grazing systems on the use and value of the rangeland: Summary and recommendations. p. 867-884. *In* Natl. Res. Council/ Natl. Acad. Sci. Developing strategies for range management. West View Press, Boulder, Colorado.

Emmick, D.L., D.G. Fox and R.R. Seaney. 1990. The effects of grazing systems on forage and cattle productivity. p. 137-141. Proc. of the For. and Grassl. Conf. Blacksburg, Virginia, June 6-9, 1990.

Ernst, P., Y.L.P. LE Du, and L. Carlier. 1980. Animal and sward production under rotational and continuous grazing management- a critical appraisal. The role of Nitrogen in intensive grassland production. p. 119-126. Proc. Int. Sym. Wageningen, Netherlands.

Fisher, D.S., K.R. Pond, J.C. Burns, R.D. Mochrie and D.H. Timothy. 1985. Selection, mastication, and digestive tract response of cattle to plant canopy and composition. p.1117-1119. *In* Proc. of the 15th Int. Grassl. Congr. August 24-31, 1985, Kyoto, Japan.

George, J.R., and D. Obermann. 1989. Spring defoliation to improve summer supply and quality of switchgrass. Agron. J. 81:47-52.

George, J.R., and J.S. Reigh. 1987. Spring growth and tiller characteristics of switchgrass. Can. J. Plant Sci. 67:167-174.

Gillen, R.L., and R.W. McNew. 1987. Seasonal growth rates of tallgrass prairie after clipping. J. Range Manage. 40:342-345.

Greene, B.B., M.M. Eichhorn, W.M. Oliver, B.D. Nelson, and W.A. Young. 1990. Comparioson of four hybrid bermudagrass cultivars for stocker steer production J.Prod. Agric. 3:253-255.

Haferkamp, M.R., and T.D. Copeland. 1984. Shoot growth and development of Alamo switchgrass as influenced by mowing and fertilization. J. Range Manage. 37:406-411.

Harrison, C.M., and C.W. Hodgson. 1939. Response of certain perennial grasses to cutting treatments. Agron. J. 31:418-430.

Hart, R.H., G.E. Schuman, M.J. Samuel, and M.D. Smith. 1986. Time-controled grazing research in Wyoming. p.73-82. *In* J.A. Tiedeman (ed.). Short duration grazing. Washington State Univ., Pulman.

Hart, R.H., M.J. Samuel, P.S. Test and M.A. Smith. 1988. Cattle, vegetation, and economic response to grazing systems and grazing pressure. J. Range. Manage. 41:282-286.

Hart, R.H., J. Bissio., M.J. Samuel, and J.W. Waggoner Jr. 1993. Grazing systems, pasture size, and cattle grazing behavior, distribution and gains. J. Range Manage. 46:81-87.

Hepworth, K.W., P.S. Test, R.H. Hart, M.A. Smith, and J.W. Waggoner Jr. 1991. Grazing systems, stocking rates, and cattle behavior in southeast Wyoming. J. Range Manage. 44:259-262.

Hildreth, R.J., and M.E. Riewe. 1963. Grazing production curves. II. Determining the economic optimum stocking rate. Agron. J. 55:370-372.

Hoveland, C.S. 1968. Bahiagrass for forage in Alabama. AL. Agric. Exp. Stn. Circ. 140.

Hoveland, C.S., C.C. King, E.M. Evans, R.R. Harris and W.B. Anthony. 1971. Bermudagrass for forage in Alabama. AL. Agric. Exp. Stn. Bull. 328.

Hudspeth, E.B., and H.M. Taylor. 1961. Factors affecting seedling emergence of Blackwell switchgrass. Agron. J. 53:331-335.

Hyder, D.N. 1974. Morphogenesis and management of perennial grasses in the United States. *In* K.W. Kreitlow and R.H.

Hart (eds.). Plant morphogenesis as basis for scientific management of the range resources. USDA Misc. Pub. 1271.

Jensen, H.P., R.L. Gillen, and F.T. McCollum. 1989. Effects of grazing pressure on defoliation patterns of Tallgrass prairie. Soc. of Range Manage., Abstr. papers. 42:109.

Jensen, N.K., and A. Boe. 1991. Germination of mechanically scarified neoteric switchgrass seed. J. Range Manage. 44:299-301.

Jung, G.A., R.W. Rice, and L.J. Koong. 1985. Comparison of heifer weight gains and forage quality for continuous and short duration grazing systems. J. Range Manage. 38:144-148.

Kee, D.D., D.I. Bransby, B.E. Gamble and H.W. Ivey. 1991. Continuous versus rapid rotational grazing of 'Tifton-44' bermudagrass by steers at varying stocking rates. p. 198-201. *In* Proc. Amer. For. and Grassl Conf. Columbia, Missouri, April 1-4, 1991.

Kee, D.D., D.I. Bransby, B.E. Gamble and H.W. Ivey. 1993. Continuous and rapid rotational grazing of bahiagrass with steers at varying stocking rates. p. 61-64. *In* Proc. Amer. For. and Grassl Conf. Des Moines, Iowa, March 29-31, 1993.

Kothmann, M.M. 1984. Concepts and principles underlying grazing systems: A discussant paper. p. 903-916. *In* Natl. Res. Council/Natl. Acad. Sci. Developing strategies for rangeland management. Westview Press, Boulder, CO.

Krueger, C.R., and D.C. Curtis. 1979. Evaluation of big bluestem, indiangrass, sideoats grama, and switchgrass pastures with yearling steers. Agron. J. 71:480-482.

Lehnert, E.R. 1985. Seven years of planned grazing systems data on twelve Central and North Central Nebraska ranches. Soc. Range Manage. Abstr. 38:24.

Maposse, I.C., D.I. Bransby, S.E. Sladden, and D.D. Kee. 1995a. Biomass yields from switchgrass varieties over six years in Alabama. p. 138. In Agronomy Abstracts. ASA, Madison, WI.

Maposse, I.C., D.I. Bransby, D.D. Kee, B.E. Gamble, and W.Gregory. 1995b. Effect of stocking rate on stocker weight gains from Alamo switchgrass in Alabama. p. 24-27. *In* Proc. Amer. For. and Grassl. Conf. Lexington, Kentucky, March 13-14, 1995.

Martin, S.C., and C.R. Whitfield. 1973. Grazing systems for Arizona ranges. Ariz. Interagency Range Comm., Tucson. 36 p.

Mathews, B.W., L.E. Sollenberger and C.R. Staples. 1994. Dairy heifer and bermudagrass pasture responses to rotational and continuous stocking. J. Dairy Science. 77:224-252.

McKenna, J.R., and D.D. Wolf. 1987. No-till switchgrass establishment as affected by lime, phosphorus and carbofuran. p. 106-110. *In* Proc. Amer. For. and Grassl. Conf., Springfield, IL, 2-5 March, 1987.

McKown, C.D, J.W. Walker, J.W. Stuth, and R.K. Heitschmidt. 1991. Nutrient intake by cattle on rotational and continuous grazing treatments. J. Range Manage. 44:596-601.

McMeekan, C.P., and M.J. Walshe. 1963. The interrelationship of grazing method and stocking rate in the efficiency of pasture utilization by dairy cattle. J. Agric. Sci. Camb. 61:147-166.

McWilliams, J.L. 1950. Mechanical treatment and age of seed affect germination of western grasses. Crops and Soils. 2:27.

Miller, M., M. Owsley, S. Sladden, and D. Bransby. 1995. Research exploring harvest management for switchgrass harvested as forage. Highl. Agric. Res. 42:16-17.

Miller, M.S., and M.R. Owsley. 1994. Harvest height and frequency effects on growth and yield of two switchgrass varieties. p. 262-266. *In* Proc. Amer. For. and Grassl. Conf. Lancaster, Pennsylvania, March 6-10, 1994.

Mooso, G.D., D.G. Morrison., C.C. Willis and G.E. Miller. 1989. Short duration versus continuous grazing for stocker beef animals. Louisiana Agric. 32:8-10.

Moser, L.E., and K.P. Vogel. 1994. Switchgrass, big bluestem and indiangrass. p 409-420. In F.R. Barnes, D.A. Miller, and C.J. Nelson (eds.). Forages: An introduction to grassland agriculture. Iowa State Univ. Press, Ames, Iowa.

Mott, G.O. 1960. Grazing pressre and the measurement of pasture production. p.606-611. *In* Proc. 8th Int. Grassl. Congr., Reading, England. 11-21 July. Alden Press, Oxford, England.

Murphy, B. 1987. Greener pastures on your side of the fence: Better farming with Voisin Grazing Management. Arriba Publishing. Colchester, Vermont.

O'Sullivan, M. 1984. Measurement of grazing behavior and herbage intake on two grazing management systems for beef production. Grassl. Beef Prod. 141-150. Dordrecht, Netherlands; Martinus Nijhoff Publishers.

Ourry, A., J. Boucaud, and J. Salette. 1990. Partitioning and remobilization of nitrogen during regrowth in nitrogen-deficient ryegrass. Crop Sci. 30:1251-1254.

Paez, A., M.E. Gonzalez-O, X. Yraus, A. Salazar, and A. Casanova. 1995. Water stress and clipping management effects on guineagrass. I. Growth and dry matter allocation. Agron. J. 87:698-706.

Panciera, M.T., G.A. Jung, and W.C. Sharp. 1985. Switchgrass seedling growth and cultivar dormancy: Potential effects on dormancy. Proc. Amer. For. Grassl. Conf. Springfield, IL, March 2-5, 1985.

Panciera, M.T., and G.A. Jung. 1989. Switchgrass establishment by conservation tillage: Planting date responses of two varieties. J. Soil and Water Conserv. 39:68-70.

Pitts, J.S., and F.C. Bryant. 1987. Steer and vegetation response to short duration and continuous grazing. J. Range Manage. 40:386-389.

Potvin, M.A. 1993. Establishment of native grass seedlings along a topographic/moisture gradient in Nebraska sandhills. Amer. Midl. Nat. 130:248-261.

Pretorious, M.W., J.O. Grunow and J.W. Rabie. 1974. Influence of frequency and intensity of defoliation on production and morphological development of Panicum maximum Jacq. cv. Sabi. Proc. grassl. Soc. Sth. Afr. 9:111-114.

Samson, J.F., and L.E. Moser. 1982. Sod-seeding perennial grasses into eastern Nebraska pastures. Agron. J. 74:1055-1060.

Sandland, R.L., and R.J. Jones. 1975. The relation between animal gain and stocking rate in grazing trials: An examination of published theoretical models. J. Agric. Sci. 85:123-128.

Sautter, E.H. 1962. Germination of switchgrass. J. Range Manage. 15:108-109.

Savory, A. 1983. The Savory grazing method or holistic resource management. Rangelands. 5:155-159.

Sharrow, S.H., and W.C. Krueger. 1979. Performance of sheep under rotational and continuous grazing on hill pastures. J. Anim. Sci. 49:893-899.

Senft, R.L. and L.M. Tharel. 1989. Interactive effects of grazing system variables on simulated cattle production and stocking rate of bermudagrass (*Cynodon dactylon*). Agric. Syst. 31:205-220.

Sims, P.L., L.J. Ayuko, and D.N. Hyder. 1971. Developmental morphology of switchgrass and sideoats grama. J. Range Manage. 24: 357-360.

Sladden, S.E., and D.I. Bransby and G.E. Aiken. 1991. Biomass yield, composition and production costs for eight switchgrass varieties in Alabama. Biomass and Bioenergy. 1:119-122.

Sladden, S.E., and D.I. Bransby. 1992. Genetic variation in morphology, yield and quality of switchgrass. p. 175-178. *In* Proc. Amer. For. and Grassl. Counc. Grand Rapids, Michigan, April 5-9, 1992.

Smith, H.R.H., D.I. Bransby and N.M. Tainton. 1986. Response of lambs to rotational and continuous grazing at four grazing intensities of Midmar Italian ryegrass. J. Grassl. Soc. South Africa. 3:56-60.

Sollenberger, L.E., W.R. Ocumpaugh, V.P.B. Euclides, J.E. Moore, K.H. Quesenberry, and C.S. Jones, Jr. 1988. Animal performance on continuously stocked 'Pensacola' bahiagrass and 'Floralta' limpograss pastures. J. Prod. Agric. 1:216-220.

Trocsanyi, Z. 1991. Water relations and cutting management of switchgrass. Dissert. Abstr. Int. Biol. Sci. and Eng. 52: 585B.

Turner, C.L., T.R. Seasted and M.I. Dyer. 1993. Maximization of aboveground grassland production: the role of defoliation frequency, intensity and history. Ecological Applications. 3:175-186.

Vallentine, J.F. 1990. Grazing management. Acad. Press, Inc. San Diego, California. 533 pp.

Vassey, T.L., J.R. George, and R.E. Mullen. 1985. Early-, mid-, and late-spring establishment of switchgrass at several seeding rates. Agron. J. 77:253-257.

Vogel, K.P., F.A. Haskins and H.J. Gorz., B.E. Anderson, and J.K. Ward. 1991. Registration of 'Trailblazer' switchgrass. Crop Sci. 31:1388.

Wallace, J.D. 1984. Some comments and questions on animal preferences, ecological efficiencies, and forage intake. p. 275-287. *In* Natl. Res. Council/Natl. Acad. Sci. Developing strategies for rangeland management. West View Press, Boulder, Colorado.

Ward, M.G., J.K. Ward, B.E. Anderson, and K.P. Vogel. 1986. Selectivity and intake of esophageal-fistulated steers grazing switchgrass. J. Anim. Sci. 63:303-304.

Weaver, J.E. 1968. Prairie plants and their environment. Lincoln: Univ. of Nebraska Press.

Wheeler, J.L., J.C. Burns, R.D. Mochrie, and H.D. Gross. 1973. The choice of fixed or variable stocking rates in grazing experiments. Exp. Agric. 9:289-302.

Wilson, A.D. 1986. Principles of grazing management systems. p. 221-225. *In* Proc. of the 2nd. Int. Rangeland Cong., Adelaide, Australia.

BIOMASS AND MORPHOLOGY OF ALAMO SWITCHGRASS AS INFLUENCED BY DEFOLIATION INTENSITY

ABSTRACT

Morphological responses of switchgrass to defoliation could impact its regrowth and persistence. A greenhouse study comprising two experiments was conducted at the Plant Science Research Center of Auburn University. Three stubble heights (5, 15 and 25 cm) were evaluated in a completely randomized design and in a randomized complete block design with five replicates. Biomass fractions (forage harvested, stubble mass and below-ground mass) increased linearly ($P<0.05$) with stubble height. A sizable tiller mortality was observed at the 5-cm stubble height with a subsequent depression in regrowth. Most of the morphological variables (leaf number, leaf area, leaf-to-stem ratio and stem length) also increased as stubble height increased. The linear increase in biomass components and morphological traits suggests that all stubble heights were suboptimal, but it is unlikely that under field conditions an optimum can be found at higher than 25-cm stubble height.

INTRODUCTION

A better understanding of the morphological response of switchgrass to defoliation is needed to maintain productive, persistent stands. Haferkamp and Copeland (1984) conducted a field-plot study with Alamo switchgrass, in which they examined shoot characteristics under different defoliation regimes. Anderson *et al.* (1989) studied the role of carbohydrate reserves in the production of regrowth. Although more emphasis has been put on storage carbohydrates, nitrogen translocated from the roots and that supplied internally play a significant role in promoting regrowth (Beaty *et al.*, 1978; Millard *et al.*, 1990; Ourry *et al.*, 1990). Despite these and other efforts, the understanding of factors that determine tillering and regrowth in switchgrass is still weak. The objective of this study was to determine the effect of stubble height on morphology and dry matter partitioning of Alamo switchgrass in the greenhouse.

MATERIALS AND METHODS

Two greenhouse experiments were conducted from spring to fall, 1996 at the Plant Science Research Center located at Auburn University, in East-Central Alabama. Individual tillers were selected from plants that had been established in the field in the spring of 1992. For the first experiment tillers were transplanted on 18 August 1995, while for the second experiment tillers were transplanted on 15 April 1996. Black pots (16.5-cm height and 21.6-cm diameter) were filled with an artificial growth medium (Marvyn loamy sand soil) and had water-permeable bottoms to allow free drainage. Upon successful tiller establishment (at least one tiller with more than 20 cm legnth in each pot), cutting treatments were applied. The cutting treatments were applied from 13 March to 7 June 1996 (Experiment 1) and from 5 July to 30 September 1996 (Experiment 2), every four weeks. A delayed start of cutting treatments in the first experiment was caused by a slow tiller establishment. Not all clones were uniform in terms of tiller number at the beginning of the first experiment, despite the attempt to select for uniform buds at transplanting. It is impossible to determine at that stage which buds will produce viable tillers, as there are several factors that determine tillering. Switchgrass tillers are known to be true biennials, with buds being formed the first year resulting in productive tillers the following year. To overcome this problem, the experiment was blocked by pot uniformity on the basis of the initial tiller count and the height of the tallest tiller. In the second experiment, there was no need for blocking, as numerous plants were potted prior to the experiment, thus allowing for selection of uniform pots for the whole experiment.

Soil was watered daily to field capacity during the establishment phase, and weekly during the course of the experiments. Also, during the establishment phase, soils received nitrogen fertilizer at a rate equivalent to 225 kg ha^{-1}. Treatments were stubble heights (5, 15 and 25 cm) with five replications. The first experiment was arranged in a randomized complete block design, while the second experiment was organized as a completely randomized design.

Just before cutting, measurements were made in each pot on tiller length and number of leaves per tiller. Leaves and stems were then harvested and separated to estimate leaf-to-stem ratio on a dry weight basis after drying at 65° C. The stem component also included sheaths, while leaves included leaf blades only. Before drying, live leaf blades were scanned by pot through an LI-COR leaf area meter (model LI-3000) and cumulative leaf area (LA) reported as the total area of leaf blades from the four harvests.

At the last cutting, additional plant parts were collected. These consisted of stubble (the portion between the cutting section and the soil surface) and the below-ground parts (BLGM) which consisted of rhizomes and roots. Total biomass was calculated as the sum of all dry matter fractions accumulated since transplanting. Forage harvested was calculated as the sum of leaf weight and stem weight. Total regrowth was calculated as the sum of leaf and stem weights from all except the first harvest. Analysis of variance with polynomial contrasts was performed on stubble height for all the response variables, followed by regression analysis using the REG procedure of SAS (1985). Correlation analysis was performed on various yield and morphological variables using the GLM procedure with MANOVA option, to adjust for treatments and blocks (SAS, 1985). Unless otherwise stated, null hypotheses were tested at the 0.05 probability level.

RESULTS AND DISCUSSION

Dry matter yield and allocation

Total biomass increased linearly as stubble height increased in both experiments, which was a direct result of linear increases in forage harvested and below-ground biomass in Experiment 1 (Figure 1). In Experiment 2 (Figure 2) total biomass increase was mainly due to increases in stubble biomass and below-ground biomass than to forage harvested. Paez *et al.* (1995) reported a linear increase in root biomass with increased stubble height of guineagrass. Similar results had been found earlier by Harrison and Hodgson (1939), working with perennial cool-season grasses.

Forage biomass in Experiment 2 did not increase significantly as stubble height increased (Figure 2). Harrison and Hodgson (1939) noted an increase in shoot growth with higher stubble height, while Hume (1991) found little response for 3- and 6-cm stubble heights in cool-season grasses. In the present study, harvested forage biomass was greater than accumulated stubble or below-ground biomass in both experiments. Stubble was the only biomass fraction not affected by stubble height in Experiment 1 (Figure 1), but increased linearly as stubble height increased in Experiment 2 (Figure 2). Total regrowth yield increased linearly with stubble height, while first harvest yield decreased linearly as stubble height increased (Figure 3). Last regrowth yield also increased linearly as stubble height increased in both experiments (Figure 4). These results suggest that short-term benefits can be achieved by harvesting very close to the ground, but long-term losses will be incurred by this regime because of stand deterioration. Miller *et al.* (1995) reported similar results from a field study.

Total regrowth yield was higher than yield from the first harvest. Since slopes of the regression lines had opposite signs, differences were accentuated with higher stubble heights. Forage biomass increased as stubble height increased, probably because more tillers survived at higher stubble heights. Fewer tillers regrew at the 15-cm stubble height, and none regrew at the 5-cm stubble height following harvest, compared to at the 25-cm stubble height. Tiller decline with low stubble height was also reported on 'Pangburn' switchgrass by Beaty and Powell (1976). Also, bud initiation may be hampered with excessive removal of leaves, since nitrogen used for bud initiation is internally supplied by the leaves (Beaty *et al.*, 1978).

Removal of leaves and depletion of total available carbohydrates (Anderson *et al.*, 1989) may have been the cause of the decline for the subsequent regrowth, which came solely from new tillers and may also have been the cause of reduced root growth. Root growth and function are dependent upon the energy produced by photosynthesis, so the suppression of root growth is proportional to the intensity of above-ground defoliation (Crider, 1955; Cook *et al.*, 1958; Youngner, 1972).

Lack of a stubble biomass response to stubble height in Experiment 1 suggested that there might have been a counteracting effect caused by compensatory tiller recruitment, but this was not observed in Experiment 2. In both experiments, below-ground biomass was greater than the stubble biomass. Stubble biomass and below-ground biomass were not correlated with forage harvested, in both experiments (Tables 1 and 2). Total regrowth yield was not correlated with below-ground biomass in both experiments (Tables 1 and 2). Lack of correlation suggests that regrowth is not highly dependent on the reserves stored in the parts located below-ground. However, Hume (1991) reported a high correlation (r=0.84) between regrowth at the end of the experiment with root weight in ryegrass (***Lolium*** sp)and prairiegrass (***Bromus willdenowii*** Kunth).

Morphology

Cumulative leaf area per plot increased linearly as stubble height increased in Experiment 1 and quadratically in experiment 2 (Figure 5). Guineagrass leaf area decreased linearly as stubble height increased under water stress, and increased linearly without water stress (Paez *et al.*,1995). Correlation between LA and total forage biomass was high in Experiment 1 (Table 1), but not in Experiment 2 (Table 2). The results in Experiment 1 stress the role of leaves and photosynthetic activity more than stored carbohydrates in regrowth. This increase in LA with stubble height may also have been due to tiller mortality at lower stubble heights. Consequently, fewer small leaves were harvested in each cut from pots under lower stubble height treatments. Linear increases also were observed for leaf number and leaf-to-stem ratio as stubble height increased in Experiment 1 (Figures 6 and 8), but LSR did not increase in Experiment 2 (Figure 8). Leaf-to-stem ratio was always greater than one in both experiments, so more of the forage harvested was in the form of leaves. This trend is expected under a short growing season in which plants are not allowed to grow past the vegetative stage. Stem length was affected by stubble height, but it did not show a clear trend in Experiment 1 (Figure 7). Stems at the 25-cm stubble height were as long as at the 5- or 15-cm stubble heights, but the 5-cm stubble height had shorter stems than the 15-cm stubble height. In Experiment 2, stem length increased linearly as stubble height increased (Figure 7).

CONCLUSIONS

As severity of defoliation increases long-term yields are reduced because regrowth is depressed. The linear increase in yield with stubble height suggests that all stubble heights used in this study were suboptimal. However, under field conditions it is uncertain what stubble heights would be recommended. The current concept of carbohydrate reserves tends to minimize the role of carbohydrate reserves in producing regrowth of aerial parts of plants, compared to leaf area. This study supports that concept, since leaf area was the most highly correlated morphological variable with biomass production, particularly of above-ground parts, even though there were simultaneous linear increases in below-ground biomass and forage harvested as stubble height increased in Experiment 1.

REFERENCES

Anderson, B., A.G. Matches, and C.J. Nelson. 1989. Carbohydrate reserves and tillering of switchgrass following clipping. Agron. J. 81:13-16.

Beaty, E.R., and J.D. Powell. 1976. Response of switchgrass, *Panicum virgatum*, L., to clipping frequency. J. Range Manage. 29:132-135.

Beaty, E.R., J.L. Engel and J.D. Powell. 1978. Tiller development and growth in switchgrass. J. Range Manage. 31:361-365.

Cook, C.W., L.A. Stoddart, and F.E. Kinsinger. 1958. Responses of crested wheatgrass to various clipping treatments. Ecol. Monogr. 28:237-272.

Crider, F.J. 1955. Root growth stoppage resulting from defoliation of grass. USDA Tech. Bull. 1102.

Haferkamp, M.R., and T.D. Copeland. 1984. Shoot growth and development of Alamo switchgrass as influenced by mowing and fertilization. J. Range Manage. 37:406-411.

Harrison, C.M., and C.W. Hodgson. 1939. Response of certain perennial grasses to cutting treatments. Agron. J. 31:418-430.

Hume, D.E. 1991. Effect of cutting on production and tillering in prairie grass (Bromus willdenowii Kunth) compared with two ryegrasses (Lolium) species. 1. Vegetative plants. Ann. Bot. London: Academic Press.

Millard, P., R.J. Thomas, and S.T. Buckland. 1990. Nitrogen supply affects the remobilization of nitrogen for the regrowth of defoliation Lolium perenne L. J. Exp. Bot. 41:941-947.

Miller, M., M. Owsley, S. Sladden, and D. Bransby. 1995. Research exploring harvest management for switchgrass harvested as forage. Highl. Agric. Res. 42:16-17.

Ourry, A., J. Boucaud, and J. Salette. 1990. Partitioning and remobilization of nitrogen during regrowth in nitrogen-deficient ryegrass. Crop Sci. 30:1251-1254.

Paez, A., M.E. Gonzalez-O, X. Yraus, A. Salazar, and A. Casanova. 1995. Water stress and clipping management effects on guineagrass. I. Growth and dry matter allocation. Agron. J. 87:698-706.

SAS Institute. 1985. SAS users guide: Statistics. SAS Institute Inc., Cary, NC.

Youngner, V.B. 1972. Physiology of defoliation and regrowth. p. 292-303. *In* V.B. Youngner and C.M. Mckell (eds.). The biology and utilization of grasses. Acad. Press, New York.

Table 1. Partial correlations of yield and morphological variables of Alamo switchgrass grown in pots in Experiment 1.

	Yield 1	Total Regrowth	Regrowth 4	Leaf area 1	Forage yield	Leaf number	Stem length
Total Regrowth	0.22						
Regrowth 4	0.06						
Forage yield	0.48			0.67*			
Leaf number		0.10	0.10	0.23	0.17		
Leaf/stem ratio	-0.25	0.60	0.59	-0.01	0.47	0.27	
Stem length	-0.00	-0.35	-0.20	-0.24	-0.32	-0.59	
Leaf area	0.37	0.97***	0.82**			0.10	-0.22
Stubble biomass	-0.48	0.39	0.53	-0.21	0.98***	-0.22	-0.16
BLGM*	0.50	0.55	0.49	0.39	0.22	0.48	-0.35
Total biomass	0.32			0.45	0.63	0.25	

	Leaf area	Stubble biomass	Leaf/stem ratio
Stem length			-0.59
Leaf area			0.56
Stubble biomass	0.33		0.65
BLGM*	0.50		0.29
Total biomass	0.87**	-0.15	0.62

*, ** and *** = Significant at the 0.05, 0.01 and 0.001 probability levels, respectively; *= Below-ground biomass.

Table 2. Partial correlations of yield and morphological variables of Alamo switchgrass grown in pots in Experiment 2.

	Yield 1	Regrowth	Regrowth 4	Leaf area 1	Forage yield	Leaf number	Stem length
Regrowth	0.27						
Regrowth 4	-0.12						
Forage yield	0.63			0.16			
Leaf number		-0.27	-0.53	0.23	-0.19		
Leaf/stem ratio	-0.14	-0.82*	-0.86*	0.48	-0.72	0.27	
Stem length	-0.33	0.65	0.81	-0.80*	0.40	-0.59	
Leaf area	0.84*	0.53	-0.02		0.76	0.10	
Stubble biomass	0.38	-0.77	-0.90	0.62	-0.47	-0.22	-0.85*
BLGM'	-0.31	-0.49	-0.04	0.13	-0.52	0.48	-0.41
Total biomass	0.15			0.44		0.25	-0.49

	Leaf area	stubble biomass	Leaf/ stem ratio
Stem length			-0.87*
Leaf area			-0.12
Stubble biomass	0.08		0.72
BLGM'	-0.45	0.18	0.43
Total biomass	-0.07		0.28

*, ** and *** = Significant at the 0.05, 0.01 and 0.001 probability levels, respectively; '= Below-ground biomass.

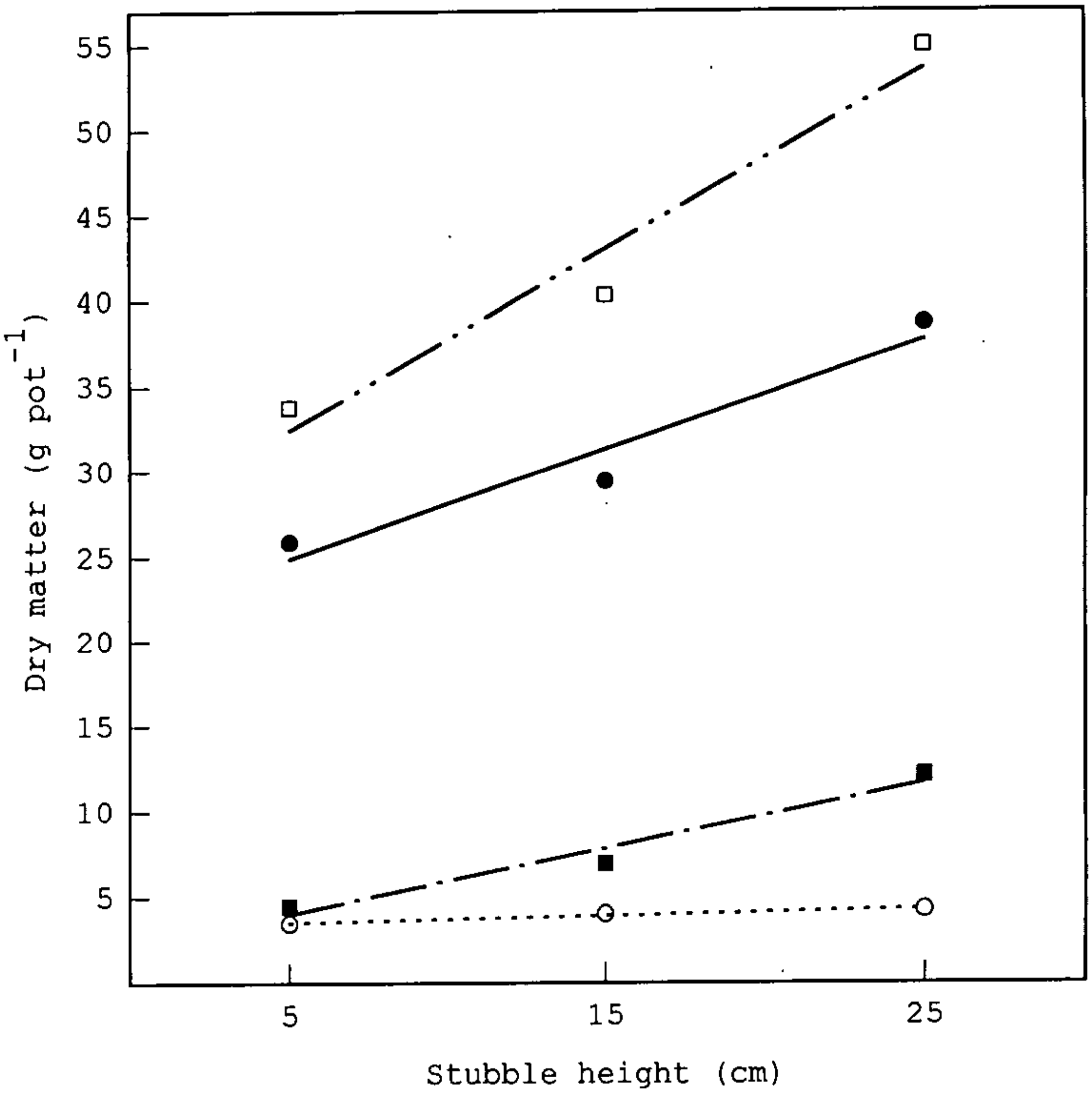

Figure 1. Dry matter of below-ground, stubble, forage and total biomass of Alamo switchgrass grown in pots, as affected by stubble height (H) in Experiment 1.

—●— Forage biomass: DM=21.681 + 0.640*H, r^2=0.07

—■·· Below-ground biomass: DM=2.110 + 0.3814*H, r^2=0.35

··○·· Stubble biomass: DM=3.329 + 0.038*H, r^2=0.26

—□·· Total biomass: DM=27.120 + 1.060*H, r^2=0.13

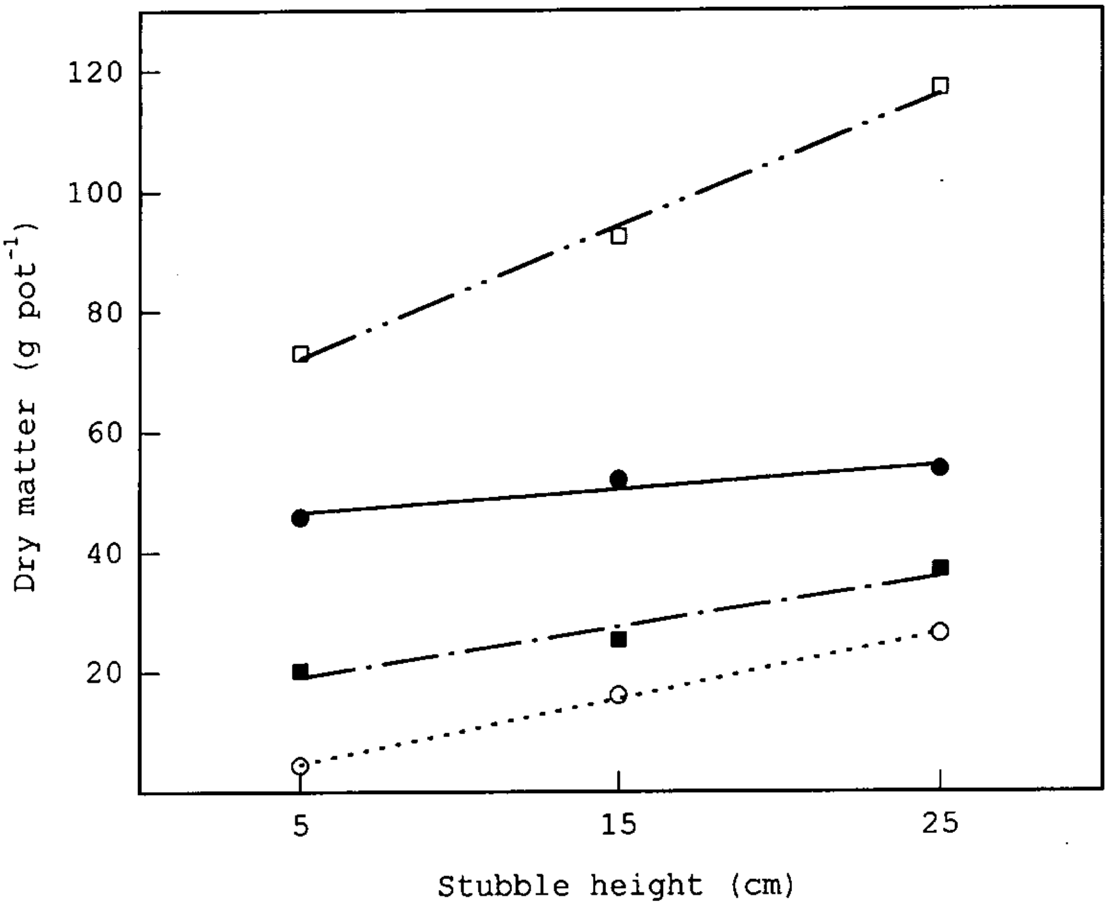

Figure 2. Dry matter of below-ground parts, stubble, forage and total biomass of Alamo switchgrass grown in pots, as affected by stubble height (H), in Experiment 2.

—●— Forage biomass: DM=44.850 + 0.384*H, r^2=0.27

—■- · Below-ground biomass: DM=15.018 + 0.850*H, r^2=0.47

· · · ○ · Stubble biomass: DM= -0.837 + 1.093*H, r^2=0.94

—□- · Total biomass: DM=61.043 + 2.216*H, r^2=0.85

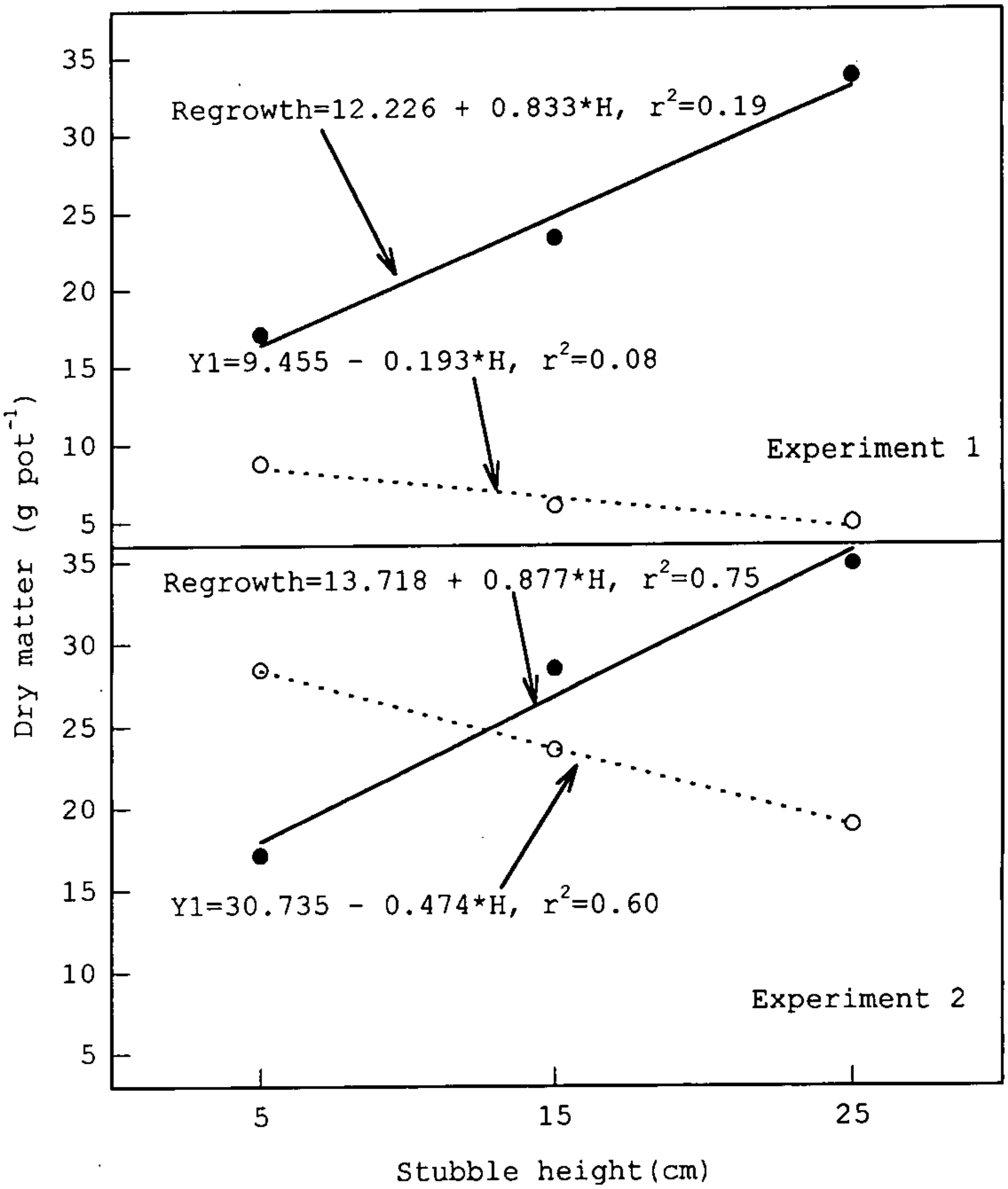

Figure 3. Effect of stubble height (H) on forage harvested at the first cut (Y1) and total regrowth of Alamo switchgrass grown in pots.

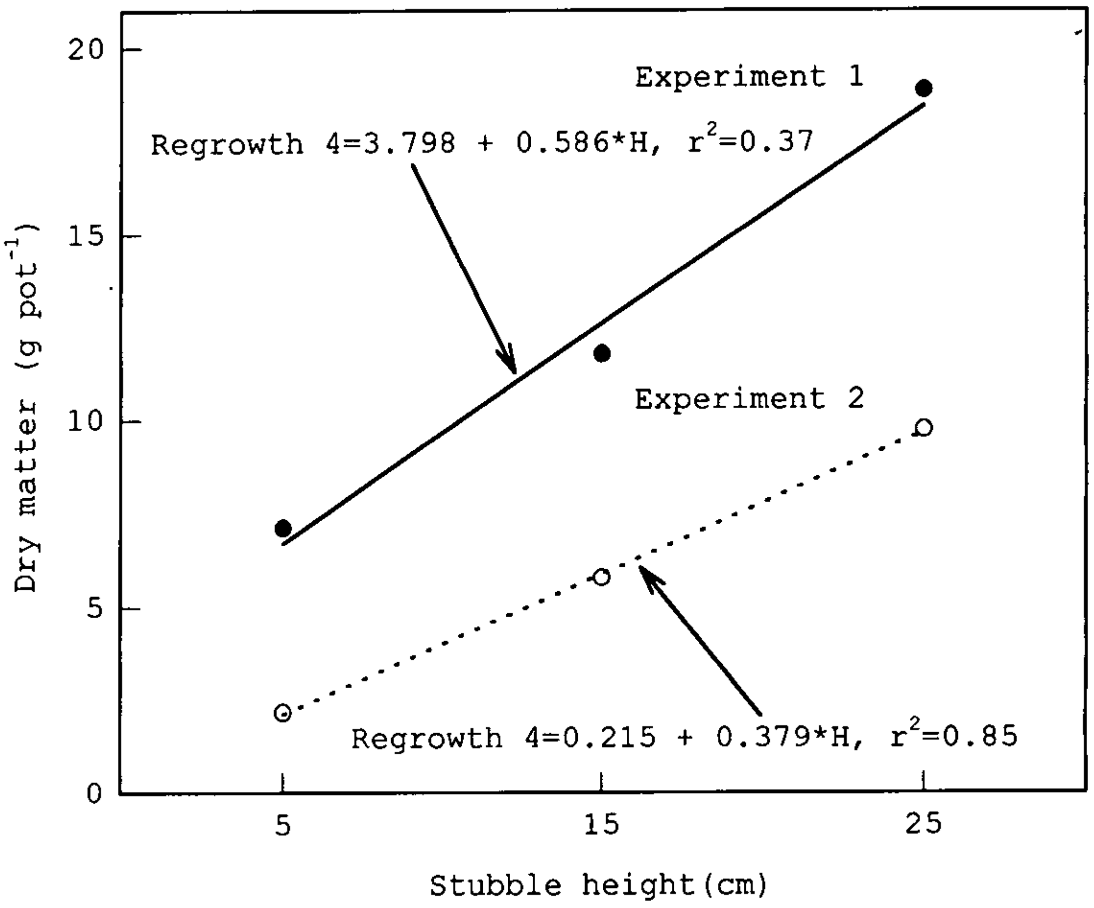

Figure 4. Effect of stubble height (H) on forage harvested at the fourth cut of Alamo switchgrass grown in pots.

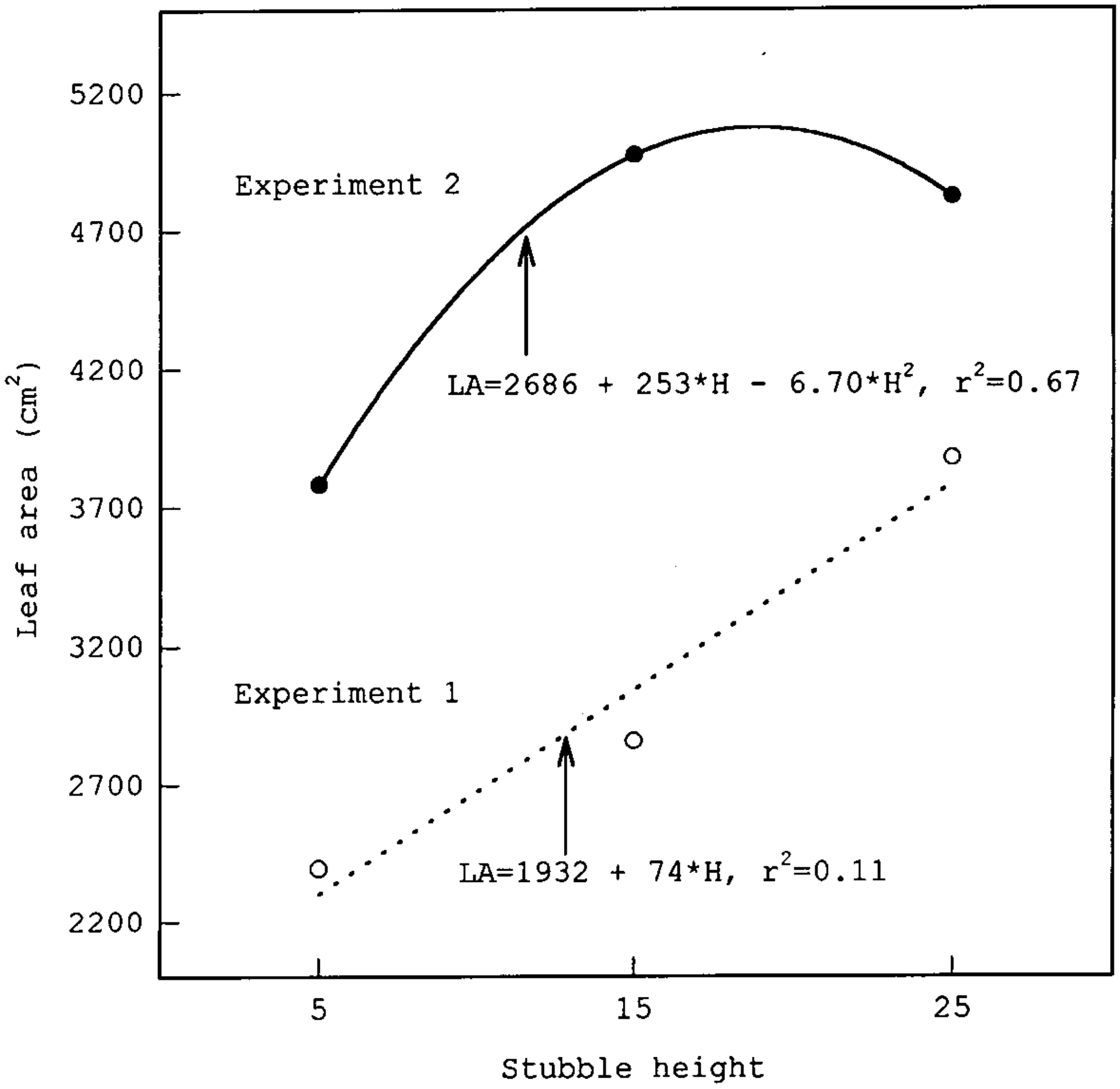

Figure 5. Effect of stubble height (H) on leaf area (LA) of Alamo switchgrass grown in pots.

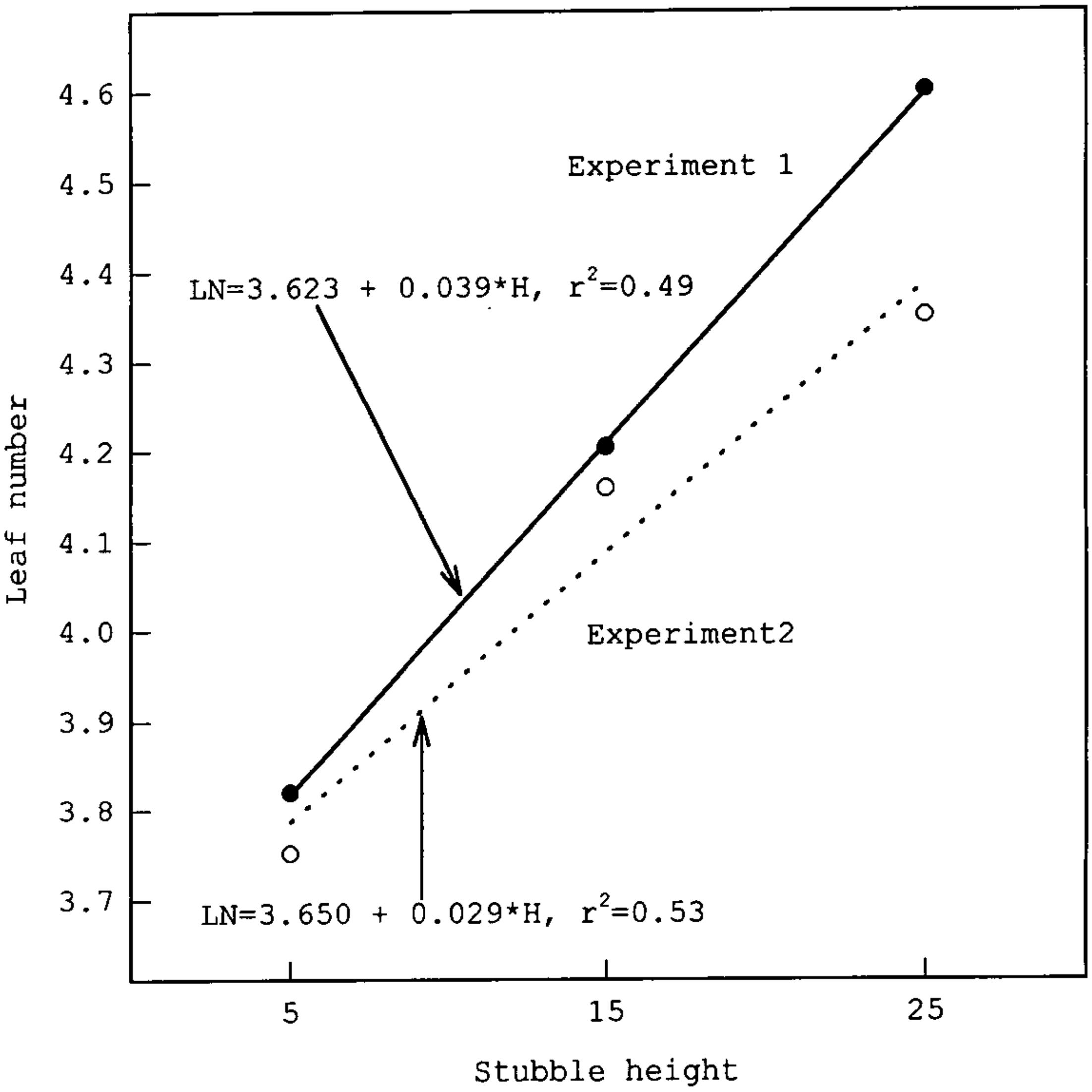

Figure 6. Effect of stubble height (H) on leaf number (LN) of Alamo switchgrass grown in pots.

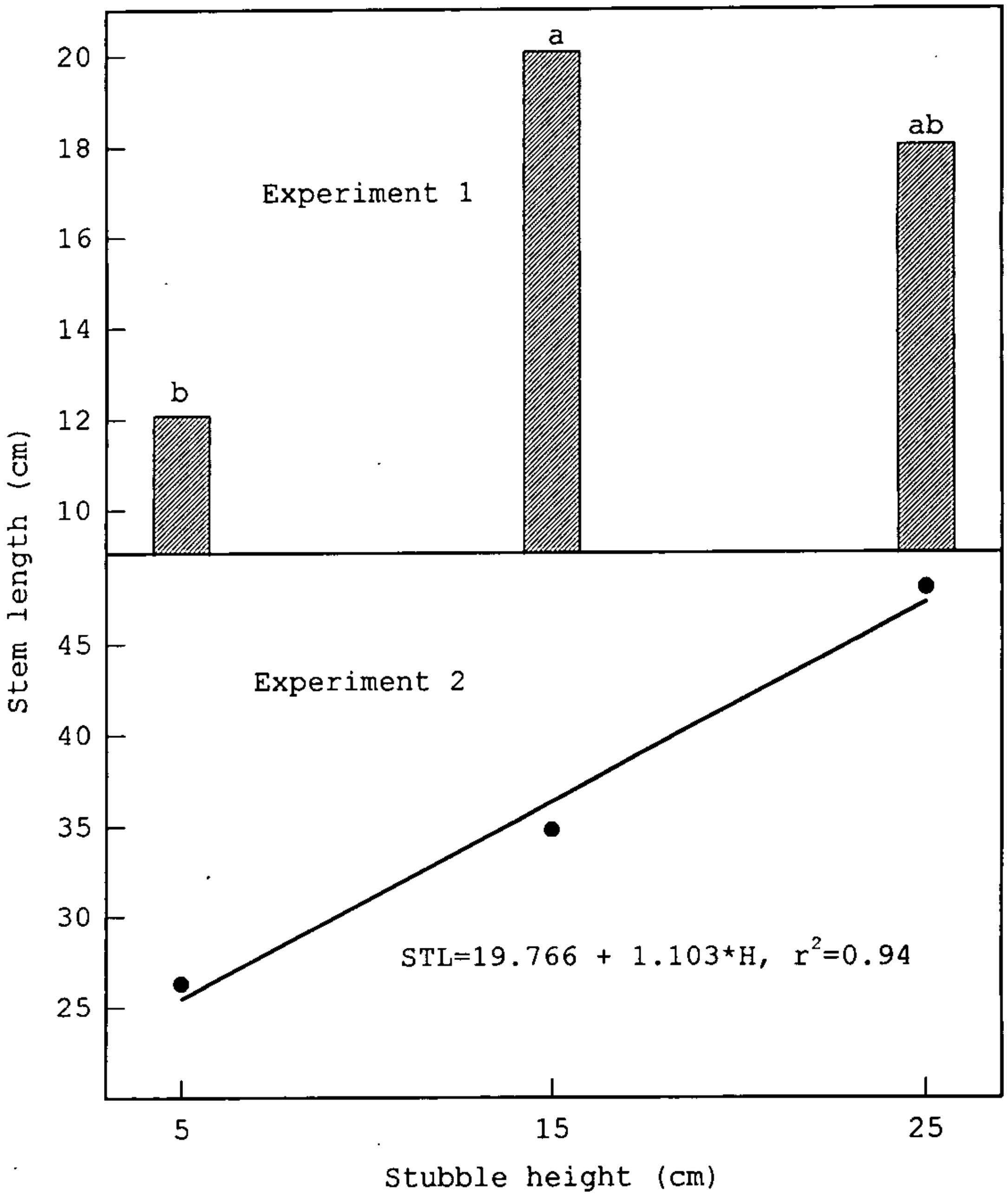

Figure 7. Effect of stubble height on stem length of Alamo switchgrass grown in pots.

a, b = Bars bearing common letters represent means that are not significantly different at the 0.05 probability level, according to the LSD test.

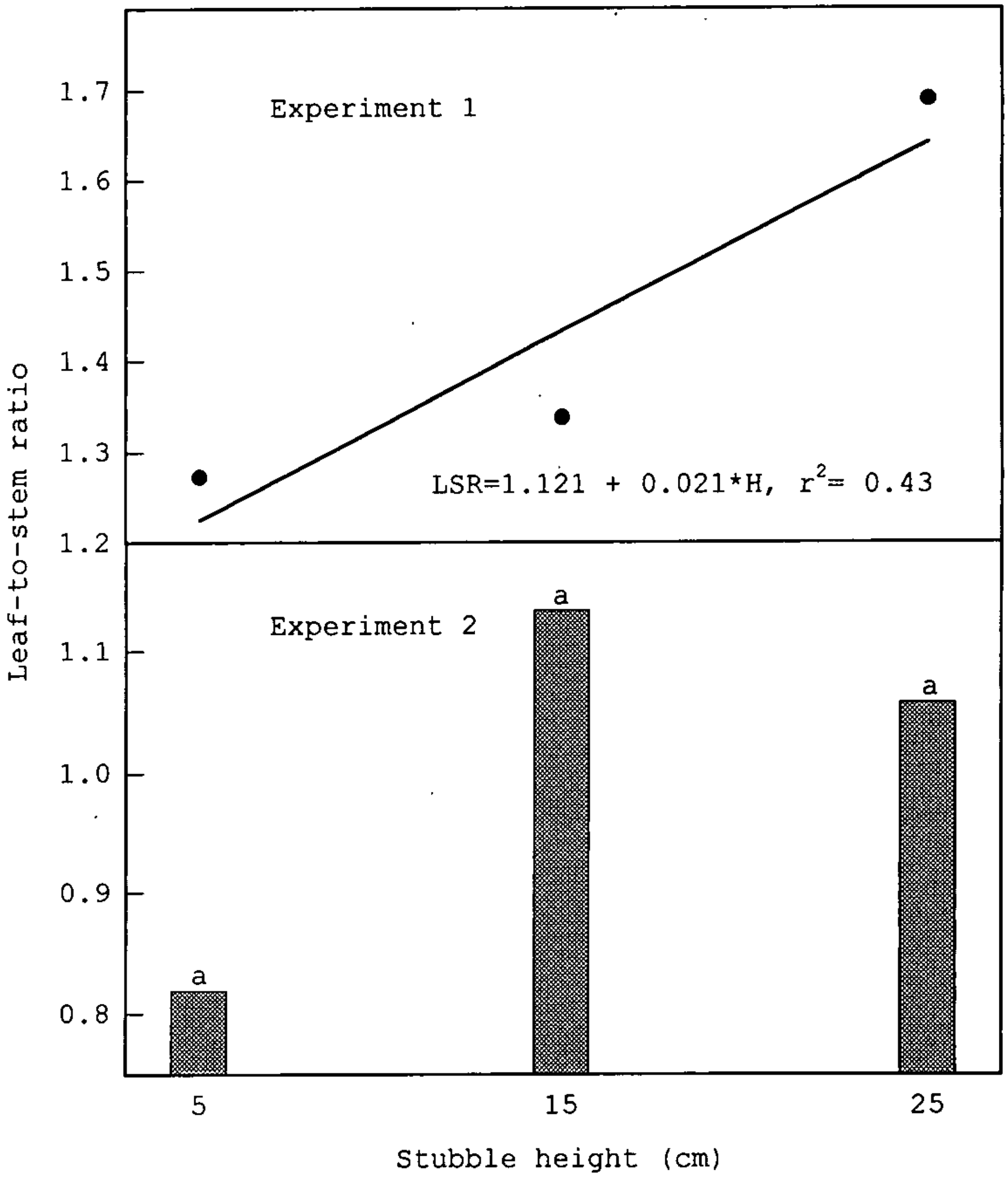

Figure 8. Effect of stubble height on leaf-to-stem ratio (LSR) of Alamo switchgrass grown in pots.

a= Bars represent means that are not significantly different at the 0.05 probability level.

FORAGE YIELD AND QUALITY OF ALAMO SWITCHGRASS AS INFLUENCED BY INITIAL CUTTING DATE AND CUTTING INTERVAL IN ALABAMA

ABSTRACT

A study was conducted with Alamo switchgrass in 1995 and 1996 at the E.V. Smith Research Center in South-Central Alabama. Treatments were date of initial cut (early or late) and cutting interval (3, 6 or 9 weeks) arranged factorially in a randomized complete block design. The first cut on early-cut plots was taken when plants reached approximately 50 cm, and the late-cut plots were harvested three weeks later. Precipitation resulted in additive yield effects except for the late first harvest for 1995. Yield at the first cut was higher for the late-cut than early-cut plots in both years, but regrowth was lower in 1995 for the late-cut plots. Regrowth on early-cut plots accounted for 94% of the season yield in 1995 and 90% in 1996, but for late-cut plots it was only 75% and 66%, respectively. Total season yield was not affected by time of first harvest in 1995, but was lower in 1996 for the early-cut plots. Yield components increased linearly with cutting interval except yield at the first cut, regrowth and total season yield of early-cut plots in 1996. In the same year, yield at the first cut on early-cut plots was not affected by cutting interval, while total season yield and regrowth yield of early-cut plots responded quadratically to cutting interval but linearly for late-cut plots. In general, forage quality of the first cut was only affected by date of first cut, while regrowth and season forage quality declined as cutting interval increased. It is concluded that time of first cut and cutting interval can affect total season yield and yield distribution of Alamo switchgrass, but the nature of response can be dependent on rainfall. Season forage quality was affected mainly by cutting interval.

INTRODUCTION

Switchgrass has potential as a forage crop in the Southeastern United States. Growth can start as early as February in Alabama (Sladden and Bransby, 1992) and March across the whole region (Beaty et al., 1978). Over a six-year trial, Alamo switchgrass produced consistently higher yields compared to eight other cultivars in Alabama. Time and interval of defoliation can impact switchgrass production. However, many studies (Beaty and Powell, 1976; Balasko et al., 1984; Haferkamp and Copeland, 1984; George and Obermann, 1989; Trocsanyi, 1991; Clavero, 1993; Brejda et al., 1994) with switchgrass have not examined the effects of time and interval of defoliation together. Furthermore, there appears to be little published work on the response of switchgrass yield to the timing of the first harvest, although George and Obermann (1989) noted that partial spring defoliation of switchgrass delayed the major supply of herbage to the latter part of the growing season. The objective of this study was to examine the effects of timing of first cut and cutting interval on total season yield, forage quality and yield distribution of Alamo switchgrass, when harvested for hay.

MATERIALS AND METHODS

A two-season (1995, 1996) study was conducted at the Field Crops Unit of the E.V. Smith Research Center, in East-Central Alabama on 3-m x 9-m plots of Alamo switchgrass that had been established in the spring of 1992. Soils are classified as Norfolk loamy sand. The treatments were date of first cut (early or late) and cutting interval (3, 6 or 9 weeks), structured as a 2 x 3 factorial in a randomized complete block design with three replicates. Plots received N at 225 kg ha^{-1}, split into two equal applications (early in spring and in mid-summer), each year. Early-cut plots were cut first on 4 April 1995 and on 29 April 1996, when plants had reached a height of approximately 50 cm. Subsequent harvests were done according to cutting interval.

On late-cut plots, the first harvest was done three weeks after the first harvest on the early-cut plots. Early-cut plots were cut first only in late April 1996 because the preceding winter had been colder (Figure 9). In addition, because frost occurred early in fall of 1996, the last harvest for the season was taken on 25 October 1996, as opposed to 3 November 1995. A flail-type Carter harvester was used to cut a 1.5-m swath at a 15-cm stubble height. All yield from several harvests but excluding the first of the growing season, was considered to be regrowth. Sub-samples of about 300 g each were weighed before and after drying at 65° C to estimate DM content. These samples were then ground in a Wiley mill to pass a 1-mm screen and analyzed for forage quality. Nitrogen content was determined using the Kjeldhal method (A.O.A.C., 1990), and crude protein was calculated by multiplying the N content by 6.25. Neutral detergent fiber and ADF were determined, following the method described by Goering and Van Soest (1970) as modified by Van Soest and Robertson (1980). Crude protein and fiber component concentrations were weighted with the respective yields to express season and regrowth forage quality.

Data were analyzed using the GLM procedure of SAS (1985), with tests for linearity and lack-of-fit for the response to cutting interval. Where these polynomial contrasts were significant, regression analysis was performed with cutting interval as a predictor. A dummy variable (with values 1 for early- and 0 for late-start) was included in the model to account for date differences and to test if the two time treatments had a common slope (Draper and Smith, 1981). Tests were performed at the 0.05 significance level, unless otherwise stated. To examine the effect of rainfall on average yield per harvest, regression analysis was used with rainfall during the period of growth and cutting interval as the predictors. This was done for individual yields from each cut.

RESULTS AND DISCUSSION

Weather

Precipitation during the growing period was higher in 1996 (813 mm) than in 1995 (711 mm). Most of this precipitation (64%) was recorded in September, October and November of 1995 and was below-normal in most of the months, but in 1996 only 18% was recorded in September and October (Figure 9). These are months when low temperatures often become a growth-limiting factor, so high precipitation may not necessarily result in high yields.

Temperatures in the winter that preceded the 1996 growing season were mostly below-normal (Figure 9), except the maximum temperature, which was slightly above-normal from January to April. Consequently, initiation of spring growth was delayed in 1996. Typically, near-normal temperatures for switchgrass growth are recorded in July/August.

Forage yield

Forage yield averaged 13772 kg ha^{-1} in 1995 and 11416 kg ha^{-1} in 1996. A longer growing season in 1995 was probably the main factor responsible for the total season yield advantage for 1995. Year differences were more pronounced with the early start at the 9-wk cutting interval. Precipitation had mostly additive effects on yield (see equations below), except for late-cut plots in 1995, where yield from each harvest was not affected by precipitation. This may have been the result of growth-limiting temperatures in late fall.

Early start-95: $AY= 3199 - 1613*CI + 26*R + 5*CI*R + 164*CI^2 - 0.12*R^2$, $R^2= 0.75$

Late start-95: $AY= - 603 + 519*CI$, $r^2= 0.42$

Early- and Late start-96: $AY= - 1069 + 376*CI + 7*R$, $r^2= 0.71$

CI= Cutting interval (weeks); AY= Yield per harvest;

R= Precipitation accumulated between consecutive harvests (mm).

Yield from the first cut in 1995 was higher for the late- than early-cut plots (Figure 10), but results were reversed for the regrowth yield (Figure 11). This resulted in similar total season yield for early- and late-cut treatments (Figure 12). Regrowth yield accounted for 94% of total season yield with the early-cut plots, as opposed to 75% with the late-cut plots in 1995 (Table 3). All yield portions increased linearly as cutting interval increased, except for the early-cut plots in 1996 (Figure 12) and yield at first cut for all treatments. Miller and Owsley (1994) also reported increasing yields from Alamo and 'Cave-in-Rock' switchgrass with cutting interval, but the rate of increase was cultivar-dependent.

Yield of the first harvest was also greater for late- than early-cut plots in 1996 (Figure 10). This was probably caused by the longer growing period before the first cut for late-cut plots, which allowed for more dry matter accumulation. The date x cutting interval interaction was significant for total season yield and regrowth yield, and was probably attributable mostly to the regrowth, since first-cut yield did not show a significant interaction. This could be a developing trend reflecting residual effects of repeated harvests, but could also be a result of seasonal oscillations. For these two yield components, responses to cutting interval were linear for the late-cut plots, but there was lack-of-fit with the linear model for the early-cut plots. In this case, a quadratic model was fitted after residual analysis. Estimated maximum total season yield and maximum regrowth yield were obtained at a 6.6-week cutting interval. An early start resulted in 90% of the season yield being partitioned to the regrowth, compared to 66% for the late-cut plots (Table 3). A decrease in regrowth contribution to total season yield over time was also noted in a switchgrass variety test over six years in Alabama (unpublished data). This was accompanied by a decline in total yield for the season. Although an early start to cutting resulted in higher yields in the first season, it appeared to cause detrimental long-term effects, particularly at the 9-week cutting interval, in which year differences were more pronounced.

Forage quality

Although it is not easy to predict absolute animal performance from forage quality as measured in the laboratory, some indication of relative performance can be obtained, thus allowing for comparison of different management regimes. According to Van Soest (1994), crude protein and ADF are well correlated with digestibility, while NDF is correlated with intake, so these three parameters are good indicators of forage quality. In the present study, CP concentration ranged from just over 80 g kg^{-1} to a little over 190 g kg^{-1}. A minimum crude protein concentration in the diet for normal ruminal function has been authoritatively placed at 70 g kg^{-1}. This indicates that, under all harvest managements used in this study, crude protein concentration would not be limiting to rumen microbial requirements.

There was no interaction between date of initial cutting and cutting interval for all forage quality parameters estimated in this study. Crude protein, NDF, ADF and hemicellulose at the first cut were affected by date of initial cut, but not by cutting interval. All fiber fractions were higher when first cut was taken early compared to late in 1995, but crude protein concentration was lower. This was surprising, since maturity tends to increase fiber concentration and decrease protein concentration. Nonetheless, these results were reversed in 1996, in line with what is reported in the literature (e.g. Ugherughe, 1986). Anderson and Matches (1983) reported that for each week delay in the first harvest of switchgrass, NDF increased 14.3 g kg^{-1} at 8-cm stubble height, but only 3.7 g kg^{-1} at a 23-cm stubble height. It is possible that factors other than what was controlled in this study may have increased N uptake in the 3 weeks that followed the first cut in 1995, or drying of samples from the early-cut plots at the first harvest may have created Maillard products.

Date of initial cutting did not affect regrowth and seasonal forage quality, except in 1996 where regrowth and seasonal hemicellulose concentrations were higher with the late start compared to early start. Cutting interval decreased crude protein concentration linearly (Figures 13 and 14) and increased NDF and ADF quadratically in 1995 and linearly in 1996 (Figures 15, 16, 17 and 18). Increases in NDF and ADF with cutting interval were probably a result of cell wall maturity, particularly in the stems. It is this increase in fiber that often dilutes the crude protein. In all instances cutting interval did not affect hemicellulose concentration (Tables 4, 5 and 6). These results suggest that hemicellulose in Alamo switchgrass plants accumulates at the same rate as the other cell wall constituents.

CONCLUSIONS

These results indicate that delaying the initial cutting by three weeks affects forage yield and quality at the first cut, the regrowth and season forage yield, but not the regrowth or the season forage quality. On the other hand, longer cutting intervals decreased the seasonal and regrowth forage quality.

Linear yield and quality changes with cutting interval offer producers alternatives to manage switchgrass to achieve specific goals. Despite some inconsistencies in reponses to treatments between years, high yields of switchgrass were obtained with a simulated hay harvest.

However, long-term studies are necessary to determine how long these high yields can be sustained under various management practices. From a practical standpoint, an optimum cutting interval will probably be close to six weeks, but several additional factors will have to be evaluated together before recommendations can be properly made.

REFERENCES

A.O.A.C. 1990. Official methods of Analysis of the Association of Official Analytical Chemists. 15th ed. A.O.A.C., Washington, D.C.

Balasko, J.A., D.M. Burner, and W.V. Thayne. 1984. Yield and quality of switchgrass grown without soil amendments. Agron. J. 76:204-208.

Beaty, E.R., and J.D. Powell. 1976. Response of switchgrass, *Panicum* virgatum, L., to clipping frequency. J. Range Manage. 29:132-135.

Beaty, E.R., J.L. Engel and, J.D. Powell. 1978. Tiller development and growth in switchgrass. J. Range Manage. 31:361-365.

Brejda, J.J., J.R. Brown, G.W. Wyman, and W.K. Schumacher. 1994. Management of switchgrass for forage and seed production. J. Range Manage. 47:22-27.

Clavero, C.T. 1993. Effect of defoliation on growth, leaf area index and light interception in tropical grasses. Revista de la Facultad de Agronomia, Univ. del Zula. 10:57-67.

Draper, N.R., and H. Smith. 1981. Applied regression analysis. 2nd ed. John Wiley & Sons, New York.

George, J.R., and D. Obermann. 1989. Spring defoliation to improve summer supply and quality of switchgrass. Agron. J. 81:47-52.

Goering,H.K., and P.J. Van Soest. 1970. Forage fiber analyses (apparatus, reagents, procedures and some applications. Ag. Handbook. 379. Washington, D.C., ARS, USDA.

Haferkamp, M.R., and T.D. Copeland. 1984. Shoot growth and development of Alamo switchgrass as influenced by mowing and fertilization. J. Range Manage. 37:406-411.

Maposse, I.C., D.I. Bransby, S.E. Sladden, and D.D. Kee. 1995. Biomass yields from switchgrass varieties over six years in Alabama. p. 138. In: Agronomy Abstracts. ASA, Madison, WI.

Miller, M.S., and M.R. Owsley. 1994. Harvest height and frequency effects on growth and yield of two switchgrass varieties. p. 262-266. *In* Proc. Amer. For. and Grassl. Conf. Lancaster, Pennsylvania, March 6-10, 1994.

SAS Institute. 1985. SAS users guide: Statistics. SAS Institute Inc., Cary, NC.

Sladden, S.E., and D.I. Bransby. 1992. Genetic variation in morphology, yield and quality of switchgrass. p. 175-179. In: W. Faw (ed.). Amer. Forage and Grassl. Council, Georgetown, TX. Proc. Amer. Forage and Grassl. Conf. Vol. 1. Grand Rapids, MI, April 5-9, 1992.

Trocsanyi, Z. 1991. Water relations and cutting management of switchgrass. Dissert. Abstr. Int. and Biol. Sci. and Eng. 52: 585B.

Van Soest, P.J. 1994. Nutritional Ecology of the Ruminant. 2nd ed. Cornell University, Ithaca, New York.

Van Soest, P.J., and J.B. Robertson. 1980. Systems of analysis for evaluating fibrous feeds. P. 49-60. *In* W.J. Pidgen (ed.). Proc. Int. Workshop on Standardization of Analytical Methodology for Feeds. Otawa, Canada.

Table 3. Regrowth contribution (%) to the total season yield as affected by time of first cut and cutting interval of Alamo switchgrass at the E.V. Smith Research Center, Shorter, Alabama.

	Interval	Time		
Year	(Weeks)	Early	Late	Mean
	3	93.0^{L}	71.5^{L}	82.3^{L}
1995	6	94.6	78.0	86.3
	9	95.4	76.8	86.1
	Mean	94.3^{a}	75.4^{b}	-
				75.4
	3	91.4	59.4^{L}	78.8
1996	6	90.1	67.5	80.1
	9	89.8	70.4	-
	Mean	90.4^{a}	65.8^{b}	

$^{a,\ b}$= Means followed by different superscripts in the same year are significantly different at 0.05 level, according to the F-test.

^{L}= Linear contrasts for the means in the same column and same year are significant at 0.05 level, according to the F-test.

Table 4. First harvest hemicellulose content (g kg^{-1}), of Alamo switchgrass as affected by time of first cut and cutting interval at the E.V. Smith Research Center, Shorter, Alabama.

	Interval	Time		
Year	(Weeks)	Early	Late	Mean
1995				
	3	351	326	339
	6	347	303	325
	9	382	319	350
	Mean	360^{a}	316^{b}	-
1996				
	3	317	353	335
	6	323	350	336
	9	319	344	332
	Mean	320^{a}	349^{b}	-

$^{a,\ b}$= Means followed by different superscripts in the same year are significantly different at 0.05 level, according to the F-test.

Table 5. Regrowth hemicellulose content (g kg^{-1}), of Alamo switchgrass as affected by time of first cut and cutting interval at the E.V. Smith Research Center, Shorter, Alabama.

	Interval	Time		
Year	(Weeks)	Early	Late	Mean
1995	3	345	343	344
	6	348	347	348
	9	369	355	362
	Mean	354^{a}	348^{b}	-
1996	3	356	350	353
	6	352	363	358
	9	340	372	356
	Mean	349^{a}	363^{b}	-

[a, b]= Means followed by different superscripts in the same year are significantly different at 0.05 level, according to the F-test.

Table 6. Average season hemicellulose content (g kg^{-1}), of Alamo switchgrass as affected by time of first cut and cutting interval at the E.V. Smith Research Center, Shorter, Alabama.

Year	Interval (Weeks)	Time Early	Time Late	Mean
1995	3	345	338	341
	6	348	337	342
	9	370	347	358
	Mean	354	340	-
1996	3	352	352	353
	6	349	359	358
	9	338	364	356
	Mean	347[a]	358[b]	-

[a], [b]= Means followed by different superscripts in the same year are significantly different at 0.05 level, according to the F-test.

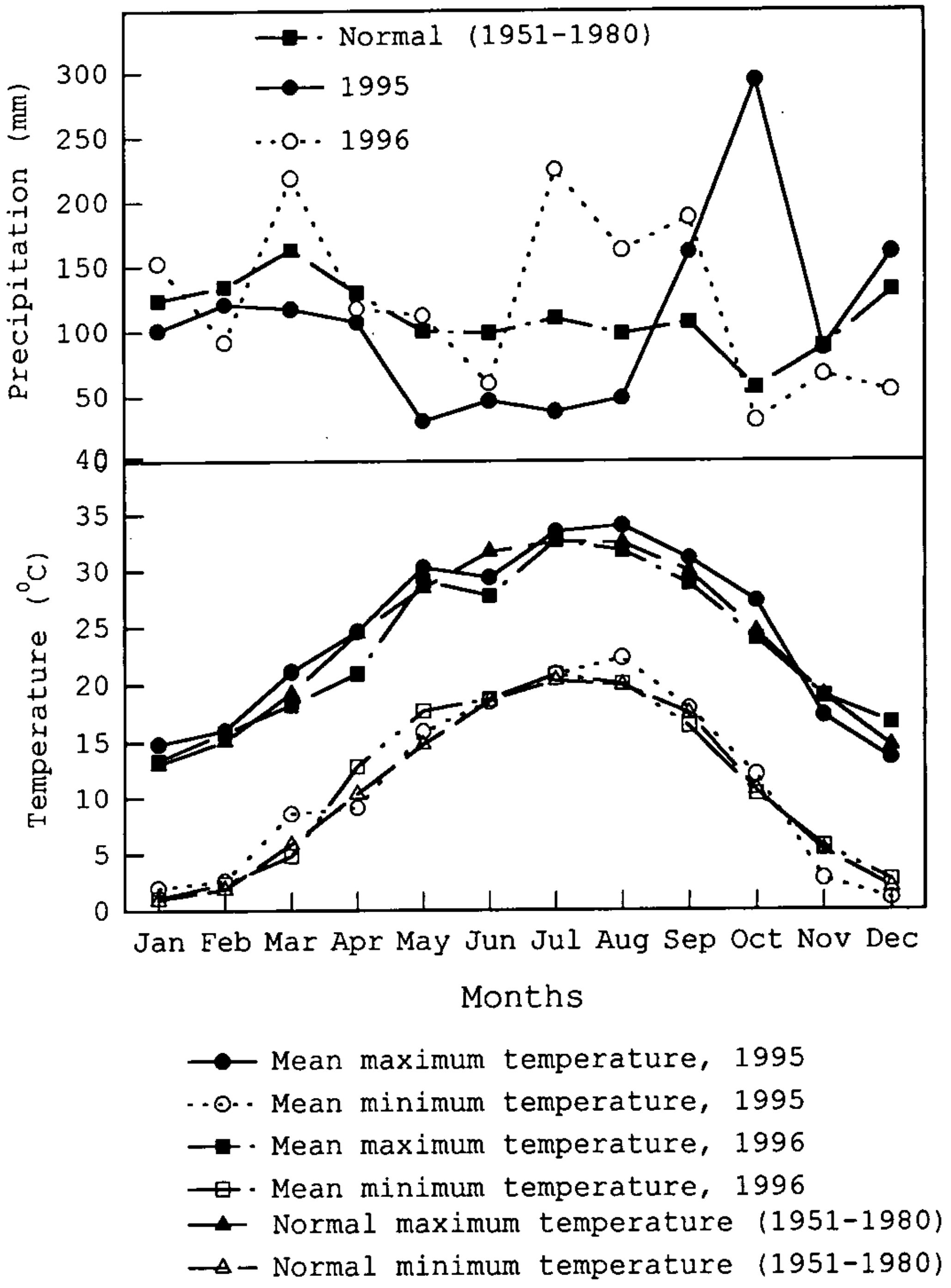

Figure 9. Monthly precipitation and air temperature at the Field Crops Unit of the E.V. Smith Research Center, Shorter, AL.

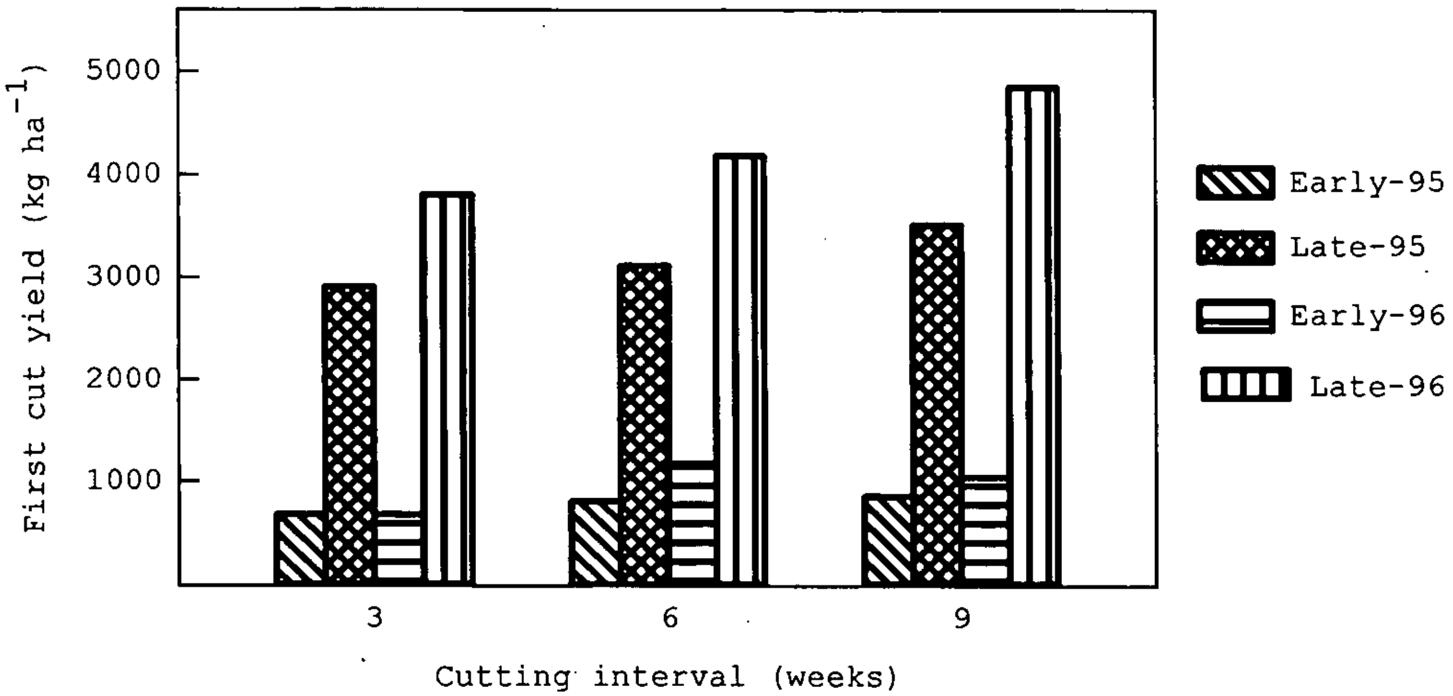

Figure 10. Effect of time of first cut (Early-95, Early-96, Late-95 and Late-96) and cutting interval on yield of first cut of Alamo switchgrass at the E.V. Smith Research Center, Shorter, AL.

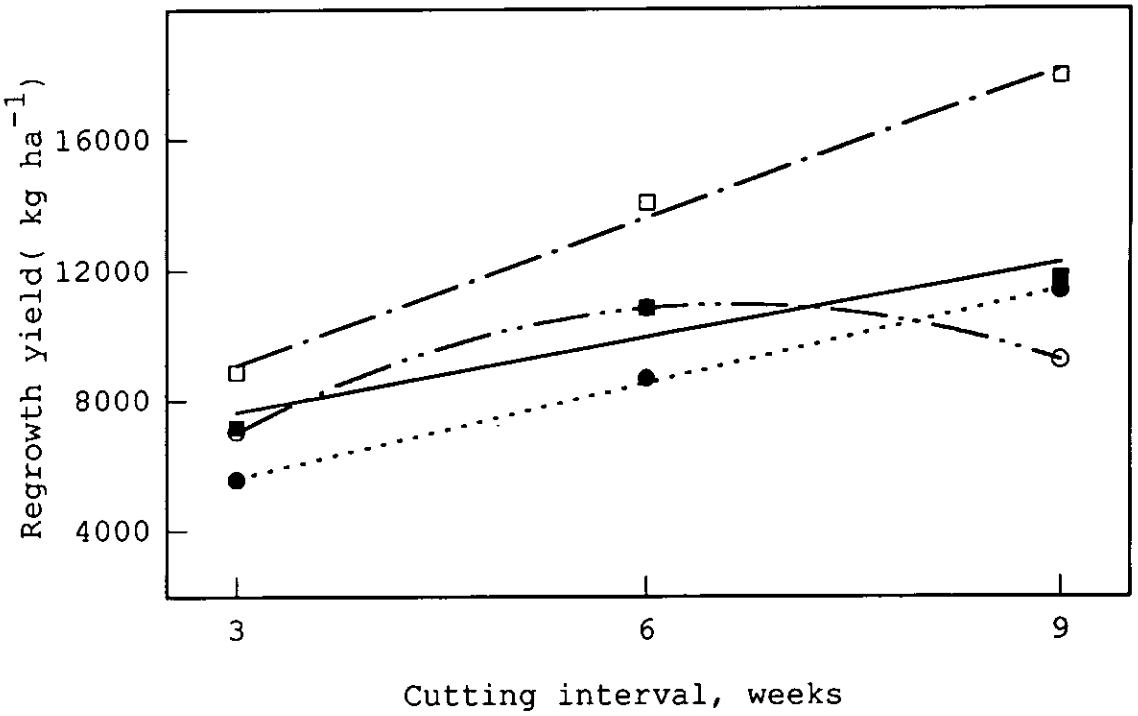

Figure 11. Effect of time of first cut and cutting interval (CI) on regrowth yield (RY) of Alamo switchgrass at the E.V. Smith Research Center, Shorter, AL.

—□· Early-95, RY=4553.5 + 1513.5*CI, r^2=0.92

—■— Late-95, RY=5346.1 + 766.0*CI, r^2= 0.54

—○· Early-96, RY= -2170.0 + 3974.8*CI - 301.0*(CI)^2, r^2= 0.79

··●·· Late-96, RY=2752.2 + 964.5*CI, r^2= 0.97

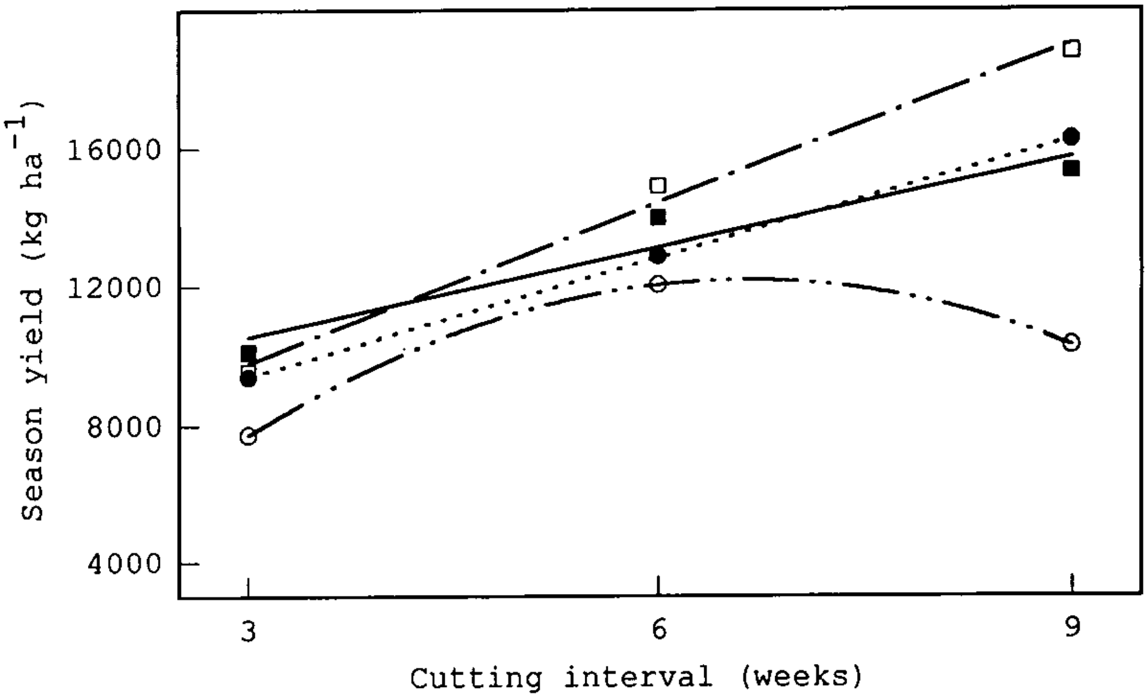

Figure 12. Effect of time of first cut and cutting interval (CI) on total season yield (TY) of Alamo switchgrass at the E.V. Smith Research Center, Shorter, AL.

□ Early-95, TY=5155.4 + 1543.4*CI, r^2= 0.91

■ Late-95, TY=7931.3 + 866.0*CI, r^2= 0.48

○ Early-96, TY= -2619.3 + 4456.7*CI -336*(CI)^2, r^2= 0.79

● Late-96, TY=5990.8 + 1139.9*CI, r^2= 0.92

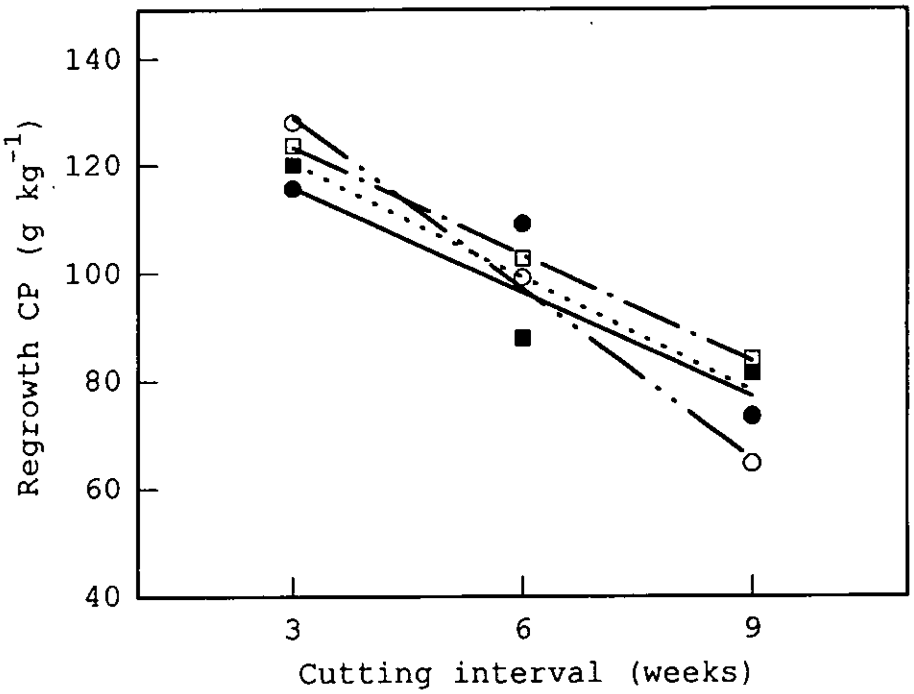

Figure 13. Effect of time of first cut and cutting interval (CI) on regrowth crude protein (CP) concentration of Alamo switchgrass at the E.V. Smith Research Center, Shorter, AL.

□ Early-95: CP=143.6 - 6.63*CI, r^2= 0.89

■ Late-95: CP=135.1 - 6.45*CI, r^2= 0.57

○ Early-96: CP=160.6 - 10.57*CI, r^2= 0.96

● Late-96: CP=141.6 - 7.06*CI, r^2= 0.76

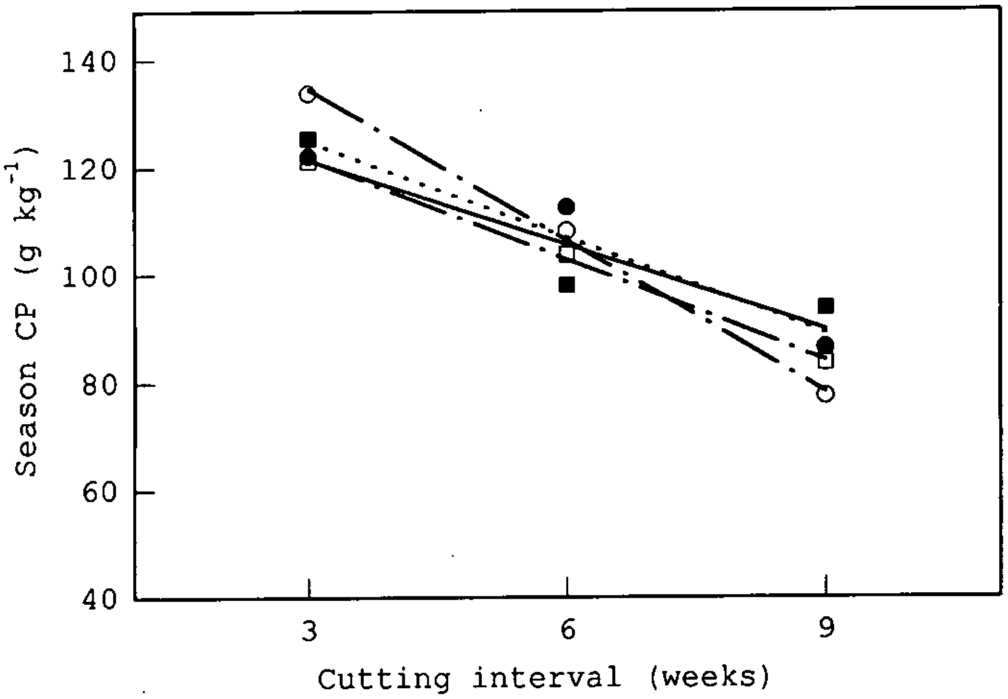

Figure 14. Effect of time of first cut and cutting interval (CI) on season crude protein (CP) concentration of Alamo switchgrass at the E.V. Smith Research Center, Shorter, AL.

—□- - Early-95: CP=140.4 - 6.26*CI, r^2= 0.89

—■— Late-95: CP=137.4 - 5.29*CI, r^2= 0.61

—○- - Early-96: CP=162.6 - 9.36*CI, r^2= 0.95

- - -● - Late-96: CP= 142.8 - 5.96*CI, r^2= 0.87

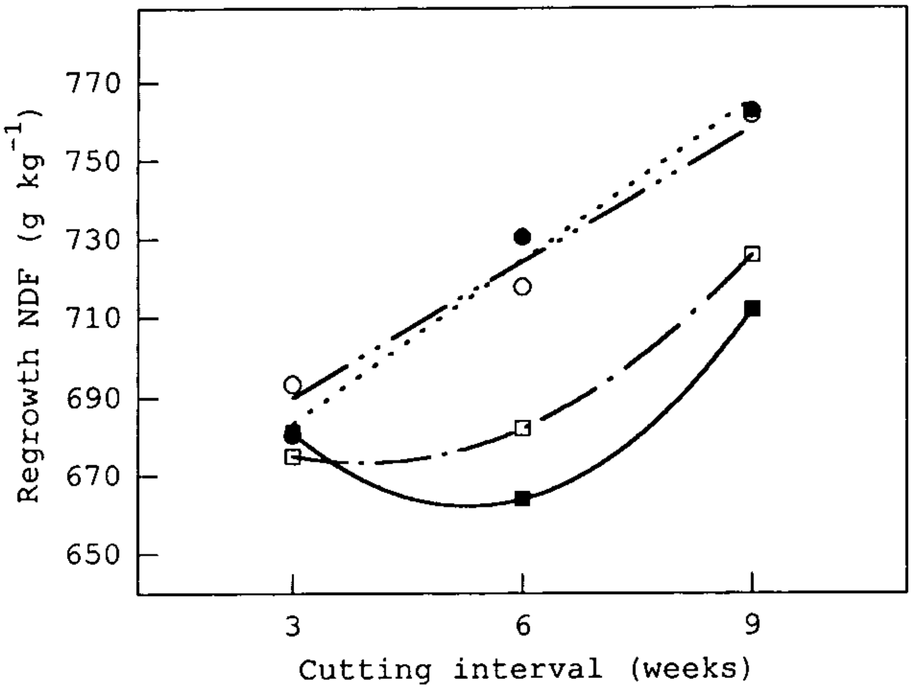

Figure 15. Effect of time of first cut and cutting interval (CI) on regrowth neutral detergent fiber (NDF) concentration of Alamo switchgrass at the E.V. Smith Research Center, Shorter, AL.

—□- - Early-95: NDF=704.5 - 15.89*CI + 2.03*(CI)^2, r^2= 0.88
—■— Late-95: NDF=763.3 - 38.26*CI +3.61*(CI)^2, r^2= 0.20
—○- - Early-96: NDF=655.8 + 11.39*CI, r^2= 0.86
- - ●- - Late-96: NDF=642.4 + 13.69*CI, r^2= 0.72

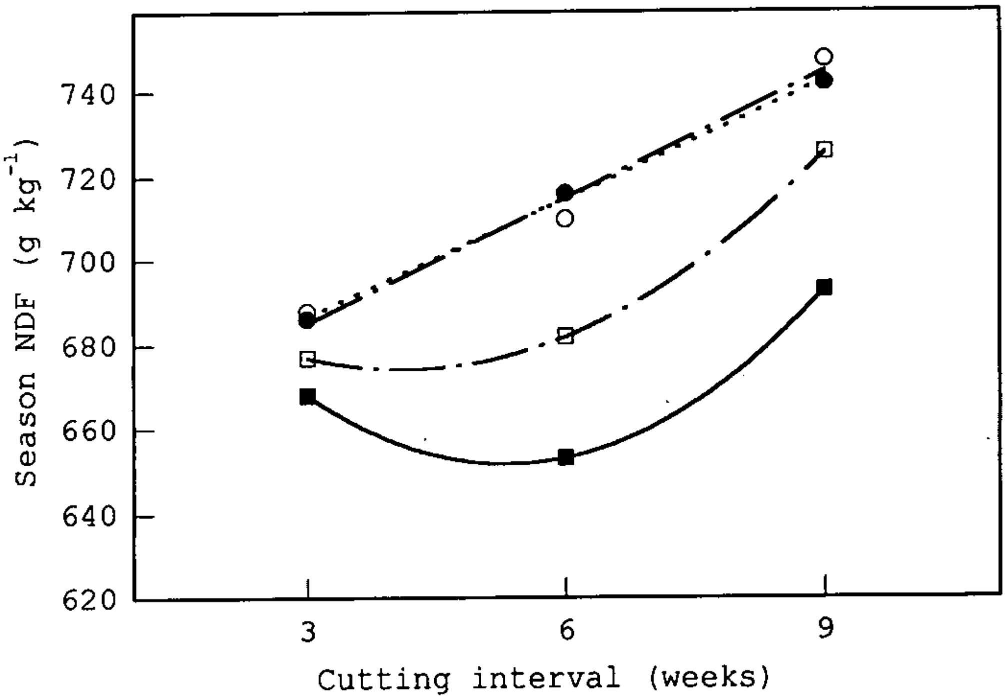

Figure 16. Effect of time of first cut and cutting interval (CI) on season neutral detergent fiber (NDF) concentration of Alamo switchgrass at the E.V. Smith Research Center, Shorter, AL.

—□- - Early-95: $NDF=710.6 - 17.76*CI + 2.16*(CI)^2$, $r^2= 0.88$

—■— Late-95: $NDF=737.6 - 32.36*CI + 3.04*(CI)^2$, $r^2= 0.19$

—○- - Early-96: $NDF=655.1 + 9.97*CI$, $r^2= 0.84$

- - ● - Late-96: $NDF=658.7 + 9.32*CI$, $r^2= 0.68$

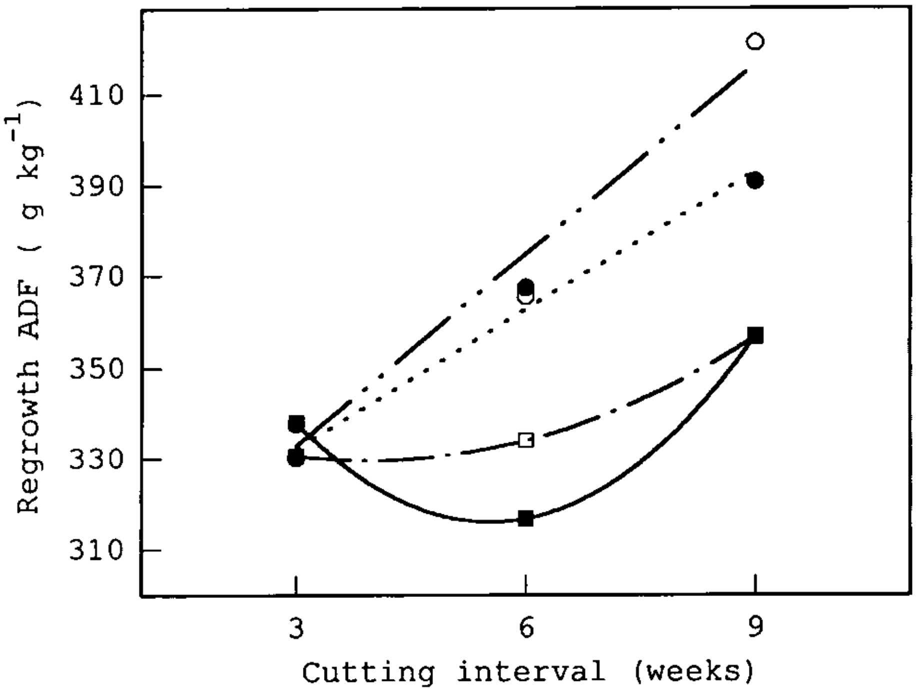

Figure 17. Effect of time of first cut and cutting interval (CI) on regrowth acid detergent fiber (ADF) concentration of Alamo switchgrass at the E.V. Smith Research Center, Shorter, AL.

□ Early-95: $ADF=346.4 - 8.43*CI + 1.06*(CI)^2$, $r^2= 0.78$

■ Late-95: $ADF=421.1 - 37.91*CI + 3.42*(CI)^2$, $r^2= 0.47$

○ Early-96: $ADF=291.3 + 13.93*CI$, $r^2= 0.91$

● Late-96: $ADF=302.1 + 10.10*CI$, $r^2= 0.79$

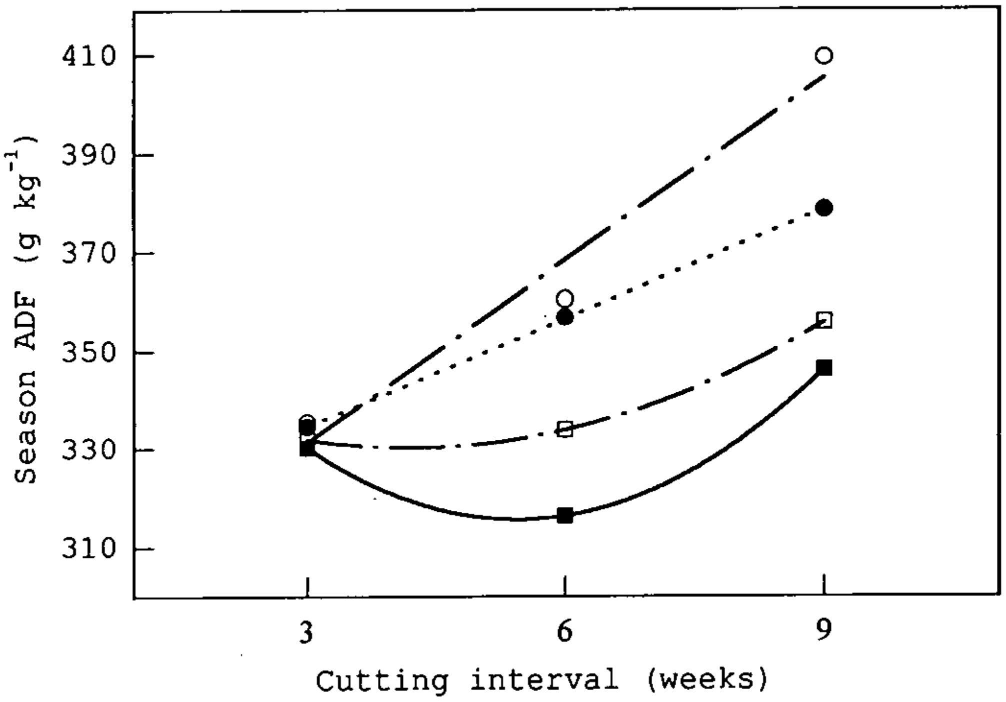

Figure 18. Effect of time of first cut and cutting interval (CI) on season acid detergent fiber (ADF) concentration of Alamo switchgrass at the E.V. Smith Research Center, Shorter, AL.

—□- - Early-95: ADF=350.0 - 9.38*CI + 1.12*(CI)^2, r^2= 0.78

—■— Late-95: ADF=387.9 - 26.54*CI + 2.43*(CI)^2, r^2= 0.42

—○- - Early-96: ADF=294.4 + 12.33*CI, r^2= 0.90

- - -● - Late-96: ADF=312.7 +7.32*CI, r^2= 0.84

CONTINUOUS AND ROTATIONAL STOCKING OF STEERS GRAZING ALAMO SWITCHGRASS IN SOUTH ALABAMA

ABSTRACT

Switchgrass is a warm-season grass with high potential for Alabama. Grazing research could determine the potential role of this forage in existing forage systems. A two-year study was conducted with steers to determine weight gain of steers and forage growth response to rotational and continuous stocking, at 5.71, 7.61 and 9.51 steers ha^{-1}. This was designed as a randomized complete block with two replications. Average daily gain declined ($P<0.10$) as stocking rate increased, only late in the season (day 84), when steers were losing weight in 1995, but there was still no response to stocking method. In 1996, responses to both stocking rate and stocking method were detected as early as day 57, when grazing on continuous stocking at 9.51 steers ha^{-1} was terminated. Overall forage height was higher under rotational than under continuous stocking. As stocking rate increased, forage height decreased linearly under continuous stocking in both years and under rotational stocking in 1996. Stem forage quality was slightly higher for continuous stocking than for rotational stocking, but was low in either

case. There is need for evaluating Alamo switchgrass as a complementary forage, since under season-long grazing, animal performance was poor and there was a progressive decline in pasture condition.

INTRODUCTION

Switchgrass could play an important role in forage systems in South Alabama, where no cool-season perennials are adapted. It is known to have a longer growing season than bahiagrass and bermudagrass, which are the most commonly grown warm-season grasses.

Alamo switchgrass has consistently produced higher yields than seven other cultivars over six years under cutting (Maposse *et al.*, 1995a). Few grazing studies have been conducted with switchgrass, although there are indications that good season-long gains can be obtained from cattle grazing it (Krueger and Curtis, 1979; Matches *et al.*, 1982; Burns *et al.*, 1984). However, poor gains were reported by Maposse et al. (1995b) in South Alabama, under season-long continuous stocking.

Animals grazing switchgrass tend to select leaves in preference to stems. This selectivity tends to lower forage quality late in the season and may result in animal weight loss. Because Alamo switchgrass often has a high proportion of stems to leaves under grazing in fall, a possible solution to this problem is close defoliation, probably by means of rotational stocking (Sollenberger *et al.*, 1988; Maposse *et al.*, 1995b), but there is no research to support this idea. Therefore, the objective of this study was to determine the effects of stocking rate and stocking method on steer performance, pasture growth and forage quality and morphology of Alamo switchgrass when grazed season-long.

MATERIALS AND METHODS

Two pastures were seeded with Alamo switchgrass on a Dothan fine sandy loam (Fine-loamy, Siliceous, Thermic, Plintic Kandiudult) soil, at the Wiregrass Substation in Southeast Alabama, in the summer of 1992 and 1993. The seed was broadcast with a fertilizer applicator at 12 kg pure live seed ha^{-1}, after which the soil was cultipacked to secure seed/soil contact. The 1992 planting used commercial seed, while seed used in 1993 was collected from the 1992 stand. The two pastures received nitrogen at 225 kg ha^{-1}, split into two equal applications (early-spring and mid-summer), each year.

Pastures were burned in January 1995 to induce uniform growth before grazing started. For logistical reasons, such as fencing, in 1996 pastures were rendered uniform by mowing rather than burning. Pastures were divided to make a total of twelve 0.53-ha paddocks, which were grazed by steers with initial weights averaging 155 kg in 1995 and 227 kg in 1996. Treatments were stocking methods (SM) (continuous stocking and rotational stocking) at 5.71, 7.61 and 9.51 steers ha^{-1}, in a complete factorial structure. The experimental design was a randomized complete block with two replications, in which paddocks were the experimental units. Pastures were the blocking criterion to account for stand age and differences in topography. Paddocks under rotational stocking had eight subdivisions, and the animals were moved twice a week in the first rotation cycle and once a week thereafter.

Animals were dewormed and fed a receiving diet based on alfalfa (*Medicago sativa* L.) hay, cracked corn (*Zea mays* L.), sugarcane (*Saccharum officinarum* L.) molasses, and other ingredients (Table 7) for approximately a month before grazing study started. Cattle in each paddock had access to a mineral block (Champions Choice Trace Mineralized Salt, Akzo Salt Inc.[1]) and clean water provided *ad libitum*, throughout the season.

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[1] Use of trade names does not necessarily imply endorsement of the product

Initial liveweight was measured on the day grazing started, and subsequent weights were taken every 28 days in the morning without fasting. Grazing started on 4 May 1995 and 25 April 1996. Average daily gain was calculated by subtracting the initial weight from the weight recorded on the weigh day and dividing the difference by the number of days grazed. On weigh days, 24 random measurements of forage height were taken with a graduated measuring stick from each paddock, to estimate forage accessibility. In addition, pairs of forage height and forage present samples were collected during the grazing season from 12-15 randomly located 61- x 61-cm quadrats using a power hedge-trimmer. The forage samples were dried, weighed, and calibrated against forage height. Forty tillers per paddock were also randomly located on or within a day of each weigh day, for leaf and stem separation. The leaf component consisted of leaf blade, while stem consisted of culm, sheath and, where present, panicle. Leaf-to-stem ratio was estimated on a dry matter basis, and used as an indicator of diet selection from the material on offer to steers. Samples were ground in a Wiley mill to pass a 1-mm screen and analyzed for Kjeldhal nitrogen (A.O.A.C., 1990), and crude protein concentration was estimated by multiplying the nitrogen content by 6.25. Neutral detergent fiber and ADF were determined according to Goering and Van Soest (1970), as modified by Van Soest and

Robertson (1980). Hemicellulose was calculated as the difference between NDF and ADF.

When grazing was terminated in 1995, eight 51- x 51-cm quadrats were located randomly in each paddock, and litter on the ground within each quadrat was collected and dried. Litter present was assumed to estimate forage losses from the combined effects of animal trampling and senescence. These data were not collected in 1996 since pastures were not burned in this year, which would have been required to separate litter from the two seasons.

Data were analyzed using the GLM procedure of SAS (1985) within each weigh day for forage height, average daily gain, leaf-to-stem ratio and litter deposition. Polynomial contrasts were also tested for stocking rate, followed by regression analysis, where significance was detected. First- and second-order models were tested and fitted between forage height and days grazed, for each stocking rate x stocking method combination in each year. A second-order model was also fitted for each SR x SM combination to relate steer weight to days grazed, where appropriate.

RESULTS AND DISCUSSION

Weather

There was more precipitation over the course of the grazing period in 1996 than in 1995 (Figure 19). However, distribution was better in 1995, as most of the precipitation fell in summer with gradual increases from May to August. In contrast, precipitation in 1996 was below 100 mm in each month from May to July, and above 200 mm from August to October. In both years, precipitation was below-normal during months of active growth (May, June and July). Temperatures were near-normal for most of the year (Figure 19). However, January, March and April of 1996 were colder than normal, which may have contributed to the delay in the initiation of growth.

Pasture growth

In four out of six cases, forage height increased in a quadratic manner as the grazing season progressed. Under continuous stocking in 1995, only in paddocks at 5.71 steers ha^{-1}, forage height changed quadratically with days grazed (Figure 20). As days grazed increased, forage height increased linearly at the 7.61 steers ha^{-1}, while it remained constant at 9.51 steers ha^{-1}. This suggests that, at 9.51 steers ha^{-1}, animal demand for forage was equal to forage availability. However, under rotational stocking, a quadratic response to days grazed was observed at all stocking rates, so rest periods allowed the plants to follow a more typical curvilinear growth pattern (Figure 20). Forage height at the end of the season in 1995 decreased linearly as stocking rate increased under continuous stocking, but not under rotational stocking (Figure 21). As a result of this interaction, differences in forage height between the two methods were more pronounced at higher stocking rates in favor of rotational stocking. This is consistent with results on tallgrass prairie containing switchgrass (Cassels *et al.*, 1995). Such differences were not observed on ryegrass/clover (*Trifolium* sp) pastures stocked with 2.5 dairy cows ha^{-1} (Evans, 1980).

When grazing was initiated in 1996, paddocks under rotational stocking had similar forage height, regardless of stocking rate, and forage was taller than in continuously stocked paddocks for the 7.61 and the 9.51 steers ha^{-1} treatments, but similar at 5.71 steers ha^{-1} (Figure 22). In paddocks under continuous stocking, initial forage height declined linearly as stocking rate increased. This suggests that plants in rotationally stocked paddocks, which had shown normal growth in 1995, accumulated enough carbohydrate reserves to resume vigorous growth, regardless of stocking rate. However, paddocks under continuous stocking, particularly at 9.51 steers ha^{-1}, were severely affected the previous season, so growth resumption was slower. Haferkamp and Copeland (1984) recommended deferment or light defoliation of Alamo switchgrass in early spring to allow the development of compound shoots and increase potential for plant regrowth. In an introduced pasture in Appalachia, Bryan and Prigge (1994) reported similar herbage biomass and species composition at initiation of grazing for paddocks that had been stocked continuously at 3, 4 and 5 steers ha^{-1} rates the previous season. The pasture was a mixture of species in which Kentucky bluegrass (*Poa pratensis* L.) was dominant with a proportion of white clover (*Trifolium repens* L.), along with other broad-leaved species.

Under continuous stocking at 5.71 and 7.61 steers ha^{-1} in 1996, there was no change in forage height with days grazed (Figure 23). Also under continuous stocking at 9.51 steers ha^{-1} forage height response to days grazed was not detectable by the time last sampling was made on this treatment (day 56), because there was no measurable forage present. Forage height responses to days grazed under continuous stocking were similar at 7.61 steers ha^{-1} (1996) and at 9.51 steers ha^{-1} (1995). This could be a reflection of carry-over effects from the first season. Under rotational stocking at 5.71 and at 7.61 steers ha^{-1}, the quadratic response observed in 1995 was still present. However, paddocks under rotational stocking at 9.51 steers ha^{-1} showed a linear increase in forage height with days grazed (Figure 23). Despite this increase, forage height was the lowest the whole season compared to the lighter stocking rates.

Forage height at the end of 1996 declined linearly as stocking rate increased for rotationally stocked paddocks (Figure 24). For continuously stocked paddocks there was also a decline in forage height, but no linear model was fitted due to early termination of grazing at 56 days for the 9.51 steers ha^{-1} stocking rate, leaving only two stocking rates.

It is evident from the observed responses that grazing intensity as characterized by stocking rate and stocking methods was the most important factor for Alamo switchgrass performance. It also seemed apparent from this study that without including the seedling stage and if plants had been left undisturbed, the typical growth response to days grazed would have been quadratic. The typical growth curve would be sigmoidal if the seedling stage was included. However, exclusion of the seedling stage in this study was acceptable since pastures were only grazed when they had grown past that stage, attaining enough growth to withstand defoliation. These growth curves suggest that, as switchgrass is grazed, over time sequences in forage height response to days grazed would be: quadratic, linear with a positive slope, no change (demand = availability), linear with a negative slope, and ultimately, no change (near bare ground). These transitions will be rapid as stocking rate increases and under continuous stocking, which would indicate that continuous stocking is likely to be undesirable, but a sound decision can be made only after considering the whole system rather than single components.

The grazing optimization hypothesis (McNaughton, 1979) suggests that above-ground production is increased somewhat by a low intensity of grazing, reduced at very high intensities of grazing, and maximized at some moderate intensities of grazing compared to production in the absence of grazing. In this study, such phenomena would have led to a quadratic response of forage height to stocking rate with a positive sign for the quadratic term. However, under both stocking methods forage height decreased linearly or remained constant as stocking rate increased.

Overcompensation occurs when the amount of replacement biomass produced exceeds the amount removed by herbivores (Turner *et al.*, 1993). This was not observed in this study, probably because overcompensation is less likely with chronic grazing, as plants have fewer reserves and less capacity to supply photosynthetic demands (Turner et al., 1993).

Calibrating forage height with forage present

A quadratic function was the best in calibrating forage height with forage present (Figure 25). This quadratic relationship could be the result of differences in tillering. In many studies with other grass species there has been high correlation between forage yield and plant height. Examples are found in (Hussain and Khan, 1973; Hussain, 1992). Therefore, if a good model is fitted there will be no need for counting tillers to predict forage accessibility. Using forage/plant height as indicators of forage present has the advantage of being easy to measure, compared to clipping samples. Furthermore, using forage height avoids destructive sampling that would lead to formation of patches which will increase selective grazing, resulting in deterioration of the pasture.

Litter deposition

There was a stocking rate x stocking method interaction for litter deposition in 1995. Dry matter losses from the canopy decreased in a quadratic manner on paddocks under rotational stocking , while on paddocks under continuous stocking the decrease was linear as stocking rate increased (Figure 26). A similar quantity of forage was wasted under continuous stocking as under rotational stocking at 5.71 and 7.61 steers ha^{-1}. However, at 9.51 steers ha^{-1} more losses occurred under rotational stocking than under continuous stocking. Gutman and Seligman (1979) and Cassels *et al.* (1995) also reported more ground litter on paddocks stocked rotationally than those stocked continuously on a mediterranean range, contrary to Hart *et al.* (1988) from a mixed range in Wyoming. More forage waste at low than at high stocking rate may have been because forage consumed was less at the low stocking rate, which left more to mature, senesce and be trampled. Higher losses at high stocking rate under rotational stocking may have been a result of high stock density, which caused overcrowding and high trampling losses when animals were confined in sub-paddocks. Heitschmidt *et al.* (1987) reported more standing litter under continuous stocking compared to rotational stocking, but confounded stocking rate with stocking methods by using a higher stocking rate in the rotationally stocked paddocks.

Leaf-to-stem ratio

Treatment effects on leaf-to-stem ratio were not observed until day 84 in 1995. Leaf-to-stem ratio had decreased linearly by this day and at equal rates between methods as stocking rate increased, but was not affected by stocking method (P>0.10) (data not presented). Rotational stocking resulted in higher leaf-to-stem ratio than continuous stocking by day 111 in 1995 (Figure 27), but stocking rate effects were only slightly significant (P<0.10). At this significance level, leaf-to-stem ratio was best described by a linear model under continuous stocking and by a quadratic model under rotational stocking. On day 146 there were still some differences between stocking methods, with rotational stocking having a slightly higher leaf-to-stem ratio (P<0.10). No treatment effects on leaf-to-stem ratio were observed on day 168 of the 1995 grazing season. Despite statistically significant differences observed late in the season, leaves averaged only 6.59% of the whole plant dry matter on day 84 and less than 5% subsequently.

In 1996, treatment differences were present as early as day 29, partly because of carry-over effects from the previous season. Plants in paddocks under continuous stocking at 9.51 steers ha^{-1} were almost devoid of leaves by day 29. Consequently, no further observations were made on this treatment. This caused a significant stocking rate x stocking method interaction, since a sizeable amount of leaves was obtained from the equivalent stocking rate under rotational stocking. For the remaining treatments in the study there were no longer stocking rate effects ($P>0.10$) or stocking rate x stocking method interaction ($P>0.10$) by day 57, but rotational stocking had a significantly higher leaf-to-stem ratio than continuous stocking. At 85 days of grazing the stocking rate x stocking method interaction reappeared (Figure 27). The advantage of rotational stocking over continuous stocking was very small at 5.71 steers ha^{-1}, compared to at 9.51 steers ha^{-1}. The probable cause of this interaction is that leaf-to-stem ratio increased quadratically under rotational stocking, while it decreased under continuous stocking as stocking rate increased. There were no treatment effects detected for leaf-to-stem ratio at 112 days of grazing ($P>0.10$); a high C.V. (85%) may have contributed to the inability to detect differences. Grazing was terminated at day 112 on paddocks under continuous stocking at 7.61 steers ha^{-1}, because animals had started to lose weight. As in 1995, leaves were a smaller portion of the total dry matter, ranging from slightly less than 10% on day 85 to about 6% on day 168.

Although some degree of leaf selection can be assessed by using leaf-to-stem ratio, under the conditions of this study leaf-to-stem ratio would not be an important variable for switchgrass management, because treatment differences were observed only when grazing could no longer be continued, as animals lost weight. However, it could be useful in monitoring long-term sward changes.

Forage quality

Forage quality for grazed pastures as measured from clipped samples does not accurately represent the quality of the diet consumed by animals, mainly because of selective grazing. However, since more than 90% of the forage present in this study was in the form of stems it is reasoned that herbage on offer comprised primarily stems, particularly late in the grazing season. Nelson and Moser (1994) indicated that stems may be more highly variable in forage quality than leaf blades, so significant improvement of forage grasses may be possible by selecting for stem quality. Therefore, only stem quality results are reported in this study.

Forage quality analysis for the 1995 grazing season was performed only for the last three weighing dates. There was a stocking rate x stocking method interaction for crude protein concentration by day 84. On day 111, stems from continuous stocking displayed more crude protein concentration than stems from rotational stocking (24 g kg^{-1} vs 21 g kg^{-1}). By day 146 neither treatment factor affected crude protein concentration.

In 1996, continuous stocking resulted in higher crude protein concentration than rotational stocking on day 57 (Figure 28). There was also an increase in crude protein concentration with stocking rate (Figure 28), but there were no treatment effects on crude protein concentration from day 85 to day 140. During this period stem crude protein concentration ranged from 32 to 40 g kg^{-1}. By day 168 of 1996, only paddocks under rotational stocking and paddocks under continuous stocking at 5.71 steers ha^{-1} were sampled (Figure 29). Under rotational stocking, crude protein concentration increased linearly as stocking rate increased. Lower crude protein concentrations could have contributed to animal weight losses caused primarily by decline in forage quantity as growth of Alamo switchgrass ceased.

Where there were differences in crude protein concentration these could probably be attributed mainly to maturity. In fact, higher stem crude protein concentration was found on continuous stocking and at higher stocking rates. It was in these cases that forage height was lower.

In 1995 NDF concentration averaged 820 and 834 g kg^{-1} on days 84 and 111, respectively, and was not affected by treatments. On day 146, NDF concentration increased quadratically as stocking rate increased under continuous stocking, but was not affected by stocking rate under rotational stocking (Figure 30). Treatments did not affect fiber concentrations in 1996. Concentrations on day 0 of grazing in 1996 averaged 673, 334 and 338 g kg^{-1} for NDF, ADF and hemicellulose, respectively; on day 140 corresponding concentrations were 816, 503 and 313 g kg^{-1}. Despite pronounced differences in growth for different treatments, it appears from fiber concentrations that maturity of stems was not dramatically affected in 1996. The apparent decline in hemicellulose from day 0 to day 140 could be an artifact of the analytical procedure since it was calculated from NDF and ADF values.

With reversed linear responses of forage height and forage quality to stocking rate, this study as a whole suggests that an optimum production level can be determined by setting constraints for forage height and forage quality parameters. However, managerial decisions aimed at optimizing forage quality and forage quantity should probably be driven mainly by forage quantity, because for the treatments used the range of forage quality variables was relatively narrow.

Steer growth curves

Cumulative weight of steers increased in a quadratic manner for all treatments, as days grazed increased in 1995 (Figure 31). However, only in paddocks under continuous stocking at 5.71 steers ha^{-1}, and under rotational stocking at all stocking rates, that weight of steers increased quadratically as days of grazing progressed in 1996 (Figure 32). In the case of continuous stocking at 7.61 and at 9.51 steers ha^{-1} steer weight never changed until grazing was terminated in 1996. Although there were no statistically significant weight changes, grazing had to be terminated at day 56 (9.51 steers ha^{-1}) and at day 112 (7.61 steers ha^{-1}), as steers lost weight. Using steer growth curves, by means of derivation it can be determined how long it takes steers to reach maximum weight. Within stocking methods, steers reached their maximum weight earlier as stocking rate increased. Under the quadratic model, once maximum weight is attained steers begin to lose weight if grazing is continued. If the maximum weight could be maintained, a hyperbolic model would be more appropriate to describe steer growth. Therefore, with the underlying response, if grazing researchers intend to perform any economic analysis, these growth curves could help in setting length of the grazing season and also to target a weight that they expect will result in a good sale price. In addition, these curves could determine when supplementation is needed (i.e, when the first derivative of the weight function is zero). The use of steer growth curves is similar to calculating intermediate average daily gains, and results would be more comparable if shorter weighing intervals were used.

Once deterioration of switchgrass forage quality is reached late in the grazing season, no further improvements in weight gains can be expected, unlike the late-season quality increase observed on hybrid bermudagrass (Carver *et al.*, 1978; Montgomery *et al.*, 1983; Greene *et al.*, 1990). One of the causes for switchgrass quality deterioration, apart from maturity, is probably that earlier in the grazing season animals grazed the top parts in a fairly uniform manner. However, as the season progressed leaves were preferentially grazed compared to stems. Vallentine (1990) indicated that selective ability is enhanced when green material is physically more separated from dead material.

Weight loss earlier in the grazing season (<84 d) was caused mainly by a shortage of forage on the heavily stocked paddocks, but later in the season (>84 d) it was a combination of a forage shortage and low forage quality. Although some basal regrowth still occurred at this period, it was a very small proportion of the forage present. Virtually all tillers were flowering after 84 days in response to photoperiodism, since switchgrass is referred to as a short-day plant (Benedict, 1941). Consequently, the animals may have been forced to eat the readily available forage, that was lower in quality. Also the high summer temperatures may have limited forage intake.

Average daily gain

Animal performance was not affected by treatments in most of the grazing period in 1995. Slight linear responses ($P<0.10$) to stocking rate were observed on day 140, but not to stocking method (Figure 33). Steers were gaining weight at lower rates or were losing weight by this time. Weight loss occurred at day 113 on continuous stocking at 9.51 steers ha^{-1}, but by day 182 all steers on the remaining treatments were already losing weight. Grazing at 9.51 steers ha^{-1} was terminated at day 113 as weight losses were recorded. This prevented us from being able to detect probable statistically significant differences among treatments that might have been present if animals had been forced to stay, regardless of their condition. However, this approach would have been excessively stressful to the animals involved. In addition, animal handling became a problem at this stage as those which ran out of forage could no longer be held in the paddocks. Some animals were seen leaning under the fence in labored efforts to grasp forage from the neighboring paddocks, while others had started jumping over the fences. If the experiment had been continued under these conditions, it would have been difficult to assess the real treatment effects. Independence among experimental units would have been violated as animals from different paddocks would have interacted.

In 1996 ADG responses to treatments were observed as early as by day 56. At this time there was a stocking rate x stocking method interaction: at 5.71 steers ha^{-1}, continuous stocking gave better average daily gain than rotational stocking; results were reversed at 7.61 and at 9.51 steers ha^{-1} in favor of rotational stocking. This was probably caused by a decline in forage quantity at 9.51 steers ha^{-1} that forced the termination of grazing under continuous stocking. Average daily gain decreased linearly as stocking rate increased, regardless of the stocking method. On day 84 the interaction was no longer present, partly because grazing had been terminated on continuous paddocks at 9.51 steers ha^{-1}, but there was still a significant decline in average daily gain as stocking rate increased.

This study has shown that cumulative average daily gain results in buffering for long grazing periods. This makes statistical tests more conservative, particularly when sensitive significance levels are chosen. Overall animal performance was poor, but gains can probably be improved if switchgrass is used as a complementary forage. It could probably be grazed early in spring, cut for hay in mid-summer and grazed in early- to mid-fall as regrowth from the hay cut.

Despite higher carrying capacity from rotational stocking in the second season, gain ha^{-1} was similar from what was achieved under continuous stocking at the low stocking rate. From a practical stand point, similar or better economic gains would have been attained under continuous stocking because lower investment in animals, fencing and additional labor would be needed. Long-term studies would be needed to determine sustainable production levels in the two methods of grazing.

Estimating average daily gain from growth curves

Average daily gains could have been estimated from the steer growth curves by using predicted weights. Differences between steer weights from specific days divided by number of days grazed in that interval will estimate the average daily gain. Ideally, if the same average daily gains are estimated from growth curves as the ones that would be obtained from observed weights, linear regression between the two sets of average daily gain data will result in a slope with value 1 and an intercept with value 0. Obviously, this is seldom observed because of random error and lack of fit. However, if steer growth curves have a fairly good fit, tests of the null hypotheses that slope is 1 and intercept is 0 should accept it. Alternatively, a paired t-test which can be performed using the MEANS procedure of SAS (1985) should also accept. In Figure 34 data from 1995 and 1996 grazing seasons are presented for this relationship. The slope was 1.02, when regression analysis was performed with the 'NOINT' option. This option forces the regression line to pass through the origin. In this case it is a necessary condition since when steers do not gain weight both methods should estimate the average daily gain at 0. Therefore, using predicted animal weights provided very similar estimates of ADG compared to using the actual data.

CONCLUSIONS

Under season-long grazing, steer performance from Alamo switchgrass was poor overall. However, strategic grazing of Alamo switchgrass (early in spring and late in summer to early in fall, with a hay cut in mid-summer), should be evaluated. Stocking rate effects on pasture growth were observed only in the second season under rotational stocking, but under continuous stocking they were evident by the end of the first season. As switchgrass was grazed in two seasons there was a progressive decline in plant growth, and this was more severe at higher stocking rates and under continuous stocking. Crude protein concentration declined, while NDF increased during the grazing period. Although continuous stocking tended to have slightly higher crude protein concentration than rotational stocking, fiber concentrations were similar. Forage quantity differences among treatments were more evident than forage quality differences, under season-long grazing. Due to changes in treatment expression from year to year, long-term studies are necessary to establish management systems of Alamo switchgrass that can be sustained under the conditions of South Alabama.

REFERENCES

A.O.A.C. 1990. Official methods of Analysis of the Association of Official Analytical Chemists. 15th ed. A.O.A.C., Washington, D.C.

Bryan, W. B., and E.C. Prigge. 1994. Grazing initiation date and stocking rate effects on pasture productivity. Agron. J. 86:55-58.

Burns, J.C., R.D. Mochrie, and D.H. Timothy. 1984. Steer performance from two perennial Pennisetum species, Switchgrass, and Fescue-Coastal Bermudagrass system. Agron. J. 76:795-800.

Cassels, D.M., R.L. Gillen, F.T. McCollum, K.W. Tate, and M.E. Hodges. 1995. Effects of grazing management on standing crop dynamics in tallgrass prairie. J. Range Manage. 48:81-84.

Carver, L.A., K.M. Barth, J.B. McLaren, H.A. Fribourg, J.T. Connel, and J.M. Bryan. 1978. Total digestible nutrient content of consumed forage and total digestible nutrient consumption by yearling beef steers grazing nitrogen-fertilized bermudagrass and orchardgrass-ladino clover pastures. J. Anim. Sci. 47:699-707.

Evans, B. 1980. Production from swards grazed by dairy cows. Supplementation and effective use of grassland for dairying. British Grassl. Soc. Hurley, Berks, U.K.

Goering,H.K., and P.J. Van Soest. 1970. Forage fiber analyses (apparatus, reagents, procedures and some applications. Ag. Handbook. 379. Washington, D.C., ARS, USDA.

Greene, B.B., M.M. Eichhorn, W.M. Oliver, B.D. Nelson, and W.A. Young. 1990. Comparioson of four hybrid bermudagrass cultivars for stocker steer production J.Prod. Agric. 3:253-255.

Gutman, M., and N.G. Seligman. 1979. Grazing management of Mediterranean foothill range in the Upper Jordan River Valley. J. Range Manage. 32:86-92.

Haferkamp, M.R., and T.D. Copeland. 1984. Shoot growth and development of Alamo switchgrass as influenced by mowing and fertilization. J. Range Manage. 37:406-411.

Harrison, C.M., and C.W. Hodgson. 1939. Response of certain perennial grasses to cutting treatments. Agron. J. 31:418-430.

Hart, R.H., M.J. Samuel, P.S. Test and M.A. Smith. 1988. Cattle vegetation, and economic response to grazing systems and grazing pressure. J. Range. Manage. 41:282-286.

Heitschmidt, R.K., S.L. Dowhower, and J.W. Walker. 1987. Some effects of a rotational grazing treatment on quantity and quality of available forage and amount of ground litter. J. Range Manage. 40:318-321.

Hussain, S.M. 1992. Interrelatioship of seedling height, mature plant height and tiller number in a local rice cultivar of Nagaland. Ind. J. of hill farming. 5: 149-150.

Hussain, M.K., and M.A. Khan. 1973. Correlation studies on sorghum-sudangrass hybrid forage. Sabrao-Newsletter. 5:51-53.

Krueger, C.R., and D.C. Curtis. 1979. Evaluation of big bluestem, indiangrass, sideoats grama, and switchgrass pastures with yearling steers. Agron. J. 71:480-482.

Maposse, I.C., D.I. Bransby, S.E. Sladden, and D.D. Kee. 1995a. Biomass yields from switchgrass varieties over six years in Alabama. p. 138. In Agronomy Abstracts. ASA, Madison, Wisconsin.

Maposse, I.C., D.I. Bransby, D.D. Kee, B.E. Gamble, and W.Gregory. 1995b. Effect of stocking rate on stocker weight gains from Alamo switchgrass in Alabama. p. 24-27. *In* G.A. Pederson (ed.). Proc. Amer. For. and Grassl. Conf. Lexington, Kentucky, March 13-14, 1995.

Matches, A.G., F.A. Martz, D.P. Mowrey, and S. Bell. 1982. Integration of subtropical perennial grasses into forage-animal systems. p. 150. *In* Agronomy Abstracts. ASA, Madison, Wisconsin.

McNaughton, S.J. 1979. Grazing as an optimization process. Grass-ungulate relationship in the Serengeti. Amer. Nat. 128:765-770.

Montgomery, C.R., B.D., Nelson, M. Allen, L. Mason, and R.P. Mowers. 1983. Evaluation of Pensacola bahiagrass and Alica bermudagrass with and without interplanted ryegrass and red clover. Louisiana Agric. Exp. Stn. Bull. 748.

Nelson, C.J., and L.E. Moser. 1994. Plant factors affecting forage quality. p. 115-154. In G.C. Fahey, Jr., D.R. Mertens, and L.E. Moser (eds.). Forage quality, evaluation and utilization. Amer. Soc. Agron, Inc., Crop Sci.Soc. of Amer., Inc., and Soil Sci. Soc. of Amer., Inc., Madison, Wisconsin.

SAS Institute. 1985. SAS users guide: Statistics. SAS Institute Inc., Cary, NC.

Sollenberger, L.E., W.R. Ocumpaugh, V.P.B. Euclides, J.E. Moore, K.H. Quesenberry, and C.S. Jones, Jr. 1988. Animal performance on continuously stocked 'Pensacola' bahiagrass and 'Floralta' limpograss pastures. J. Prod. Agric. 1:216-220.

Turner, C.L., T.R. Seasted and M.I. Dyer. 1993. Maximization of aboveground grassland production: the role of defoliation frequency, intensity and history. Ecological Applications. 3:175-186.

Vallentine, J.F. 1990. Grazing management. Acad. Press, Inc. San Diego, California. 533 pp.

Van Soest, P.J. 1994. Nutritional ecology of the ruminant. 2nd ed. Cornell University, Ithaca, New York.

Van Soest, P.J., and J.B. Robertson. 1980. Systems of analysis for evaluating fibrous feeds. p. 49-60. *In* W.J. Pidgen (ed.). Proc. Int. Workshop on Standardization of Analytical Methodology for Feeds. Otawa, Canada.

Table 7. Composition of the receiving diet fed to the steers prior to the grazing study in 1995 and 1996 at the Wiregrass Substation, Headland, Alabama.

Feed mix	Ingredient (%)
Alfalfa, Hay # 2	67.97
Corn, grain cracked	24.70
Molasses, cane	5.90
Sodium phosphate	0.60
Aureomycin-50	0.53
Salt, trace mineral	0.22
Magnesium oxide	0.07
Monensin-60	0.01

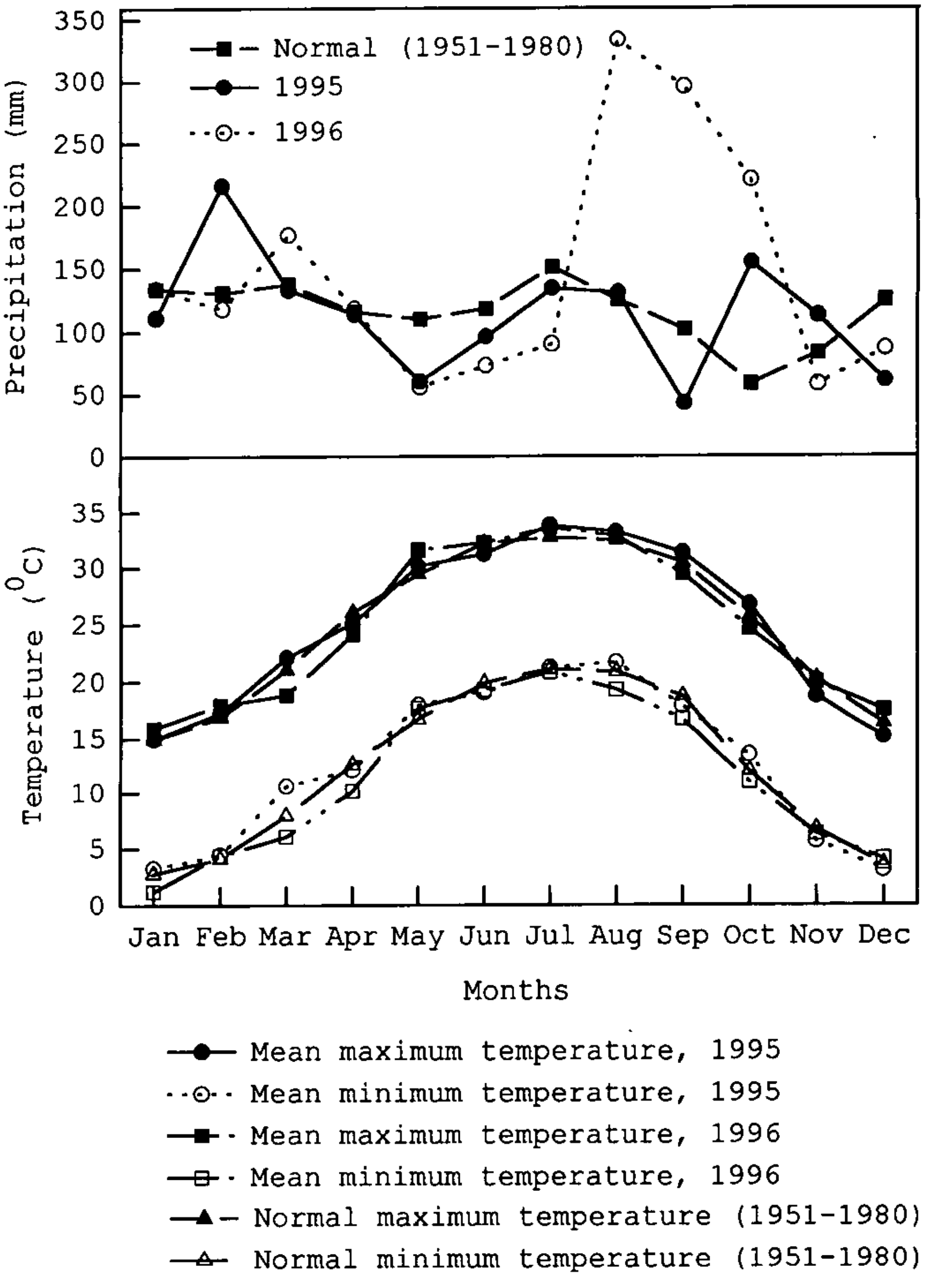

Figure 19. Monthly precipitation and air temperature at the Wiregrass Substation, Headland, AL.

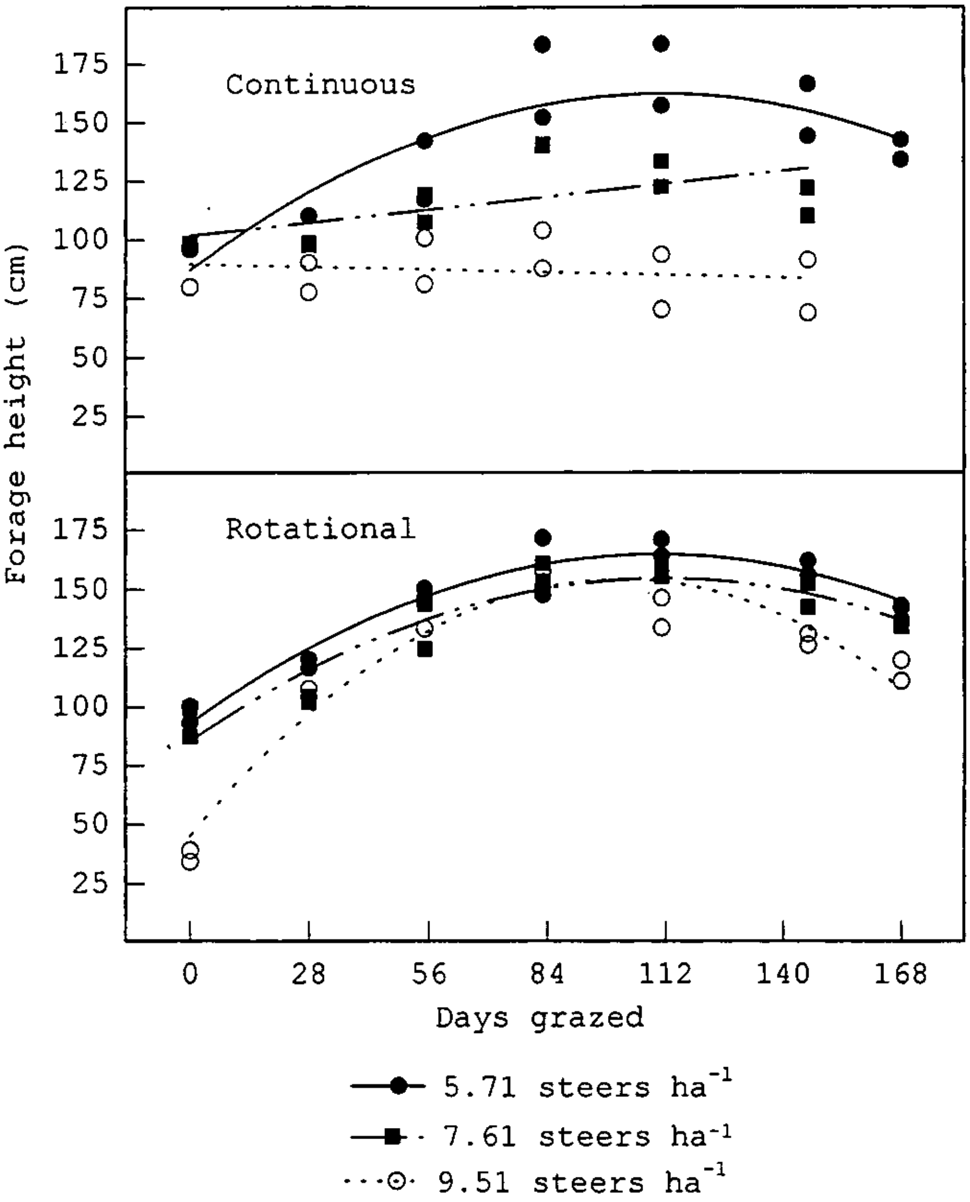

Figure 20. Effect of days grazed (d) on forage height (FH) of Alamo switchgrass at the Wiregrass Substation, Headland, AL, 1995.

Stocking method	Stocking rate (Steers ha^{-1})	Regression equations	r^2
Continuous	5.71	$FH=87.28 + 1.35*d - 0.0061*d^2$	0.77
Continuous	7.61	$FH=101.91 + 0.19*d$	0.37
Continuous	9.51	$FH=89.79 - 0.04*d$	0.04
Rotational	5.71	$FH=93.17 + 1.31*d - 0.0059*d^2$	0.94
Rotational	7.61	$FH=85.63 + 1.24*d - 0.0056*d^2$	0.88
Rotational	9.51	$FH=45.28 + 2.16*d - 0.0106*d^2$	0.94

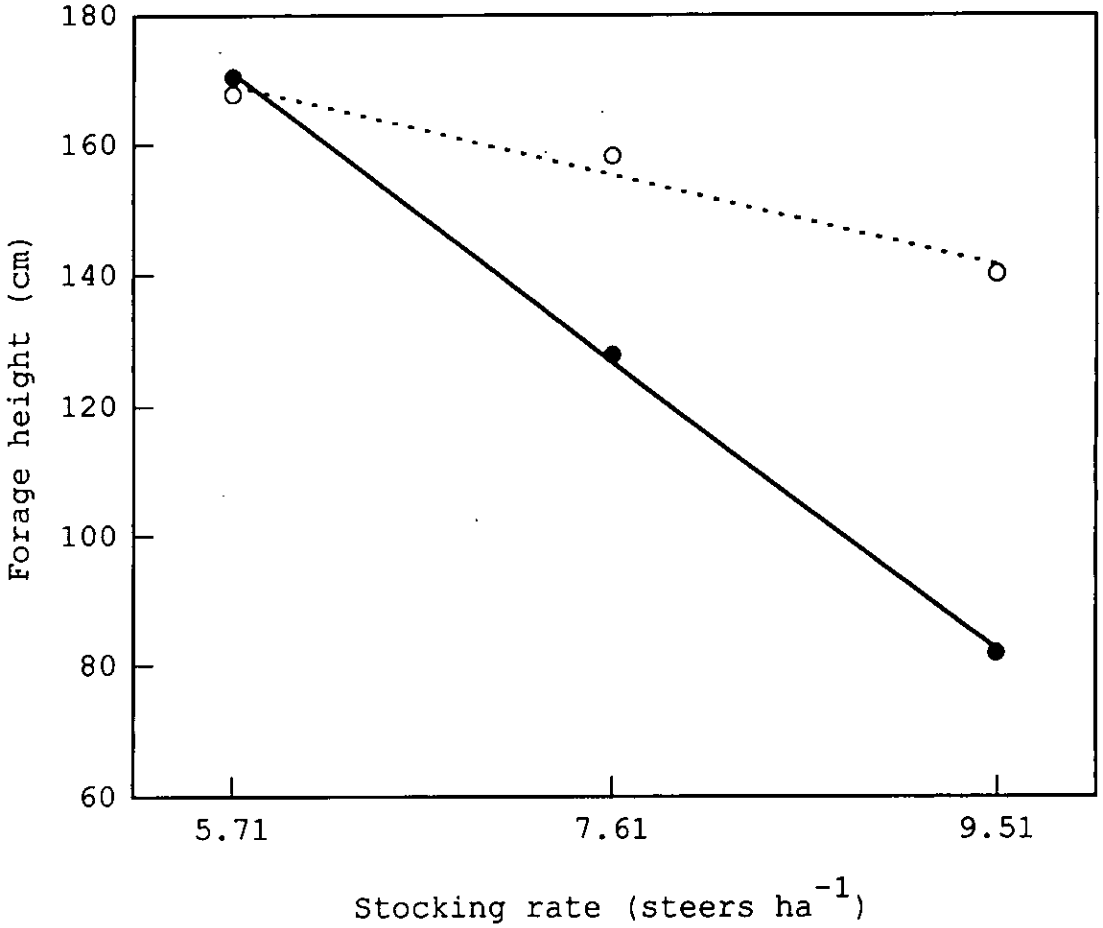

Figure 21. Effect of stocking rate and stocking method on forage height (FH) of Alamo switchgrass at the end of the grazing season, at the Wiregrass Substation, Headland, AL, 1995.

—●— Continuous: FH=210.54 - 7.262*SR, r^2=0.92

···○· Rotational: FH=303.95 - 23.298*SR, r^2=0.84

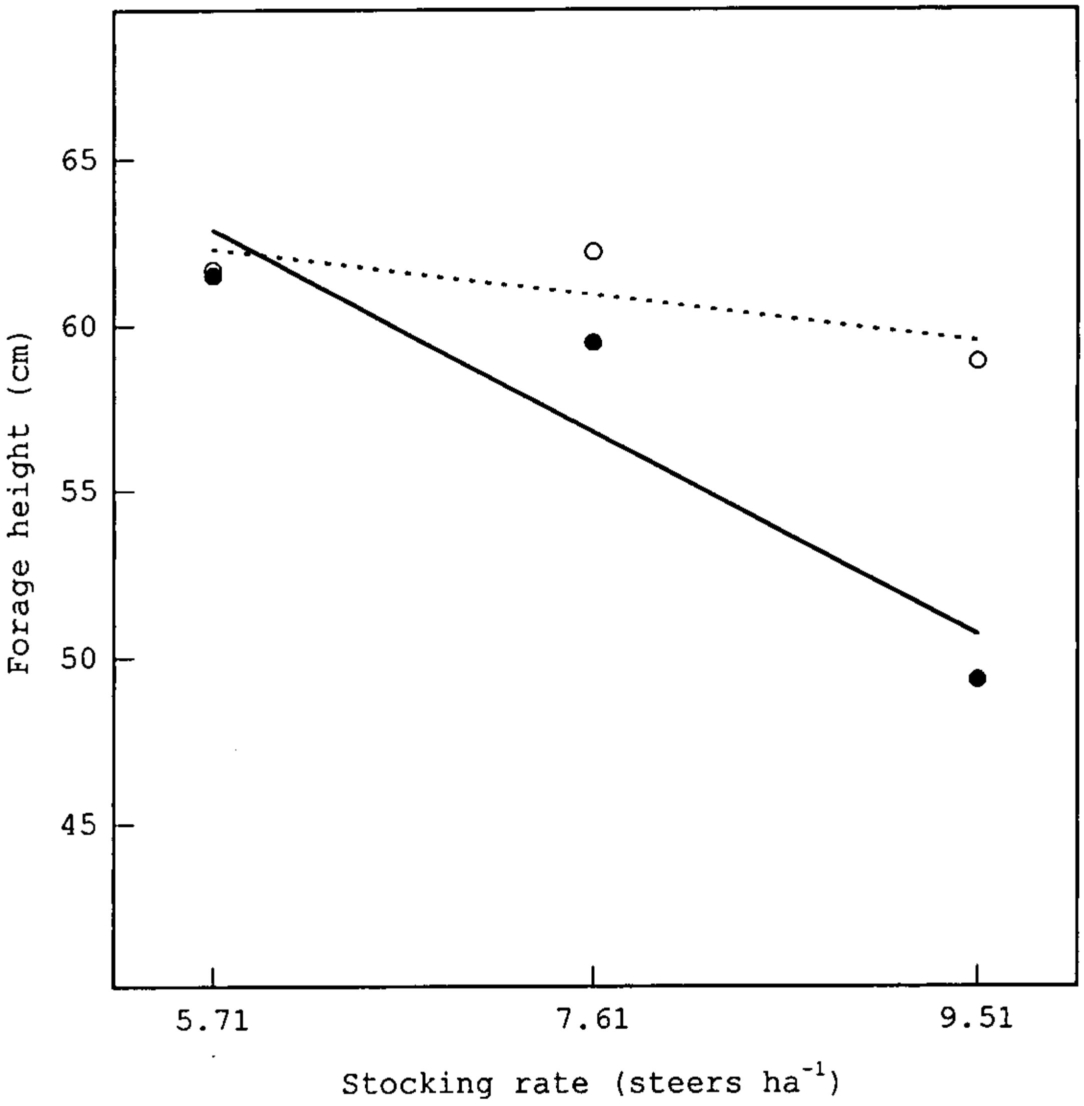

Figure 22. Forage height (FH) of Alamo switchgrass at the start of grazing in 1996, following one season of grazing at the Wiregrass Substation, Headland, AL.

—●— Continuous: FH=81.12 - 3.203*SR, r^2=0.77

··○··· Rotational: FH=66.42 - 0.725*SR, r^2=0.44

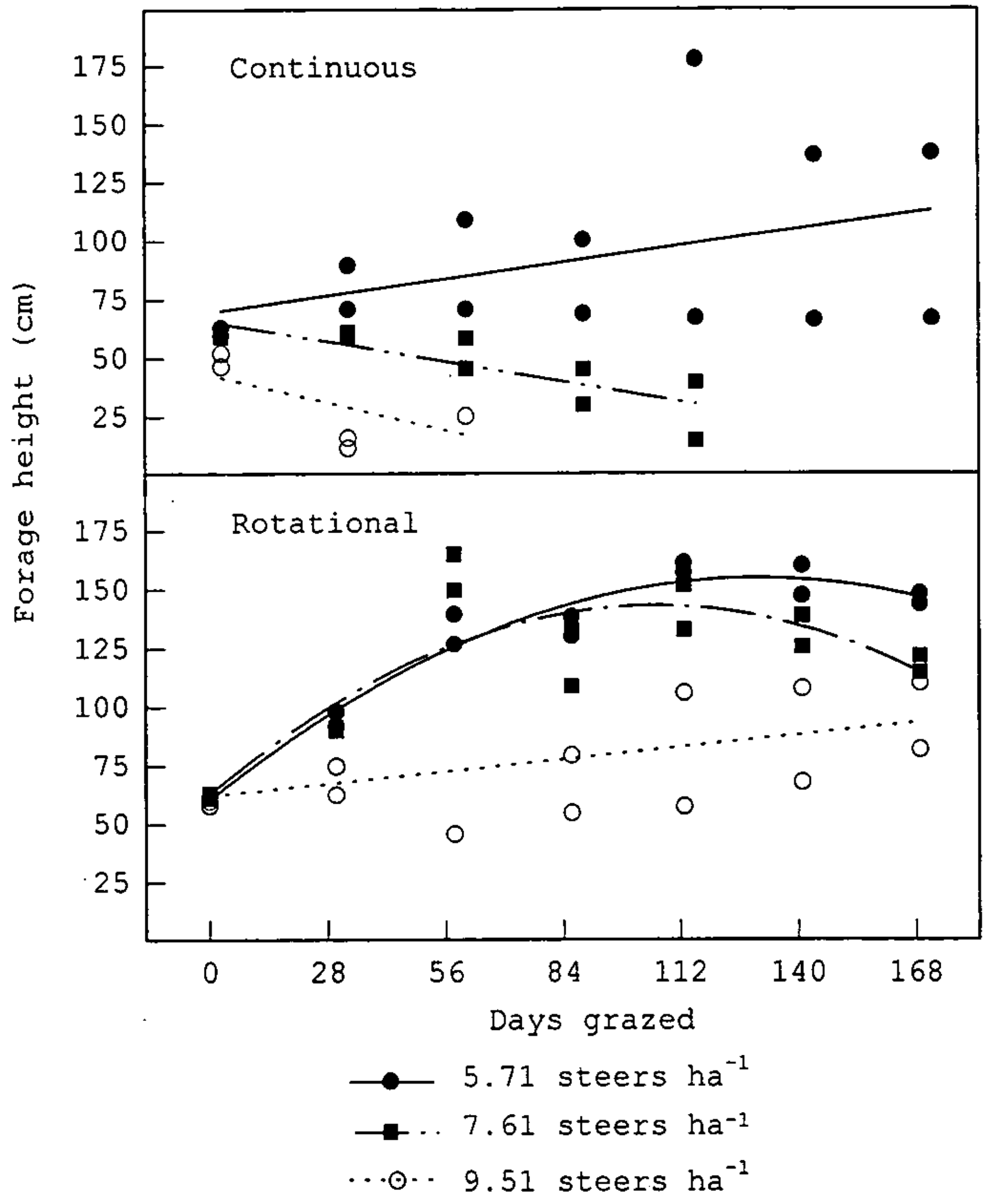

Figure 23. Effect of days grazed (d) on forage height (FH) of Alamo switchgrass at the Wiregrass Substation, Headland, AL, 1996.

Stocking method	Stocking rate (Steers ha^{-1})	Regression equations	r^2
Continuous	5.71	$FH=70.44 + 0.25*d$	0.16
Continuous	7.61	$FH=64.97 - 0.31*d$	0.69
Continuous	9.51	$FH=61.03 - 1.07*d$	0.45
Rotational	5.71	$FH=60.64 + 1.45*d - 0.0055*d^2$	0.96
Rotational	7.61	$FH=63.02 + 1.52*d - 0.0072*d^2$	0.73
Rotational	9.51	$FH=62.29 + 0.19*d$	0.19

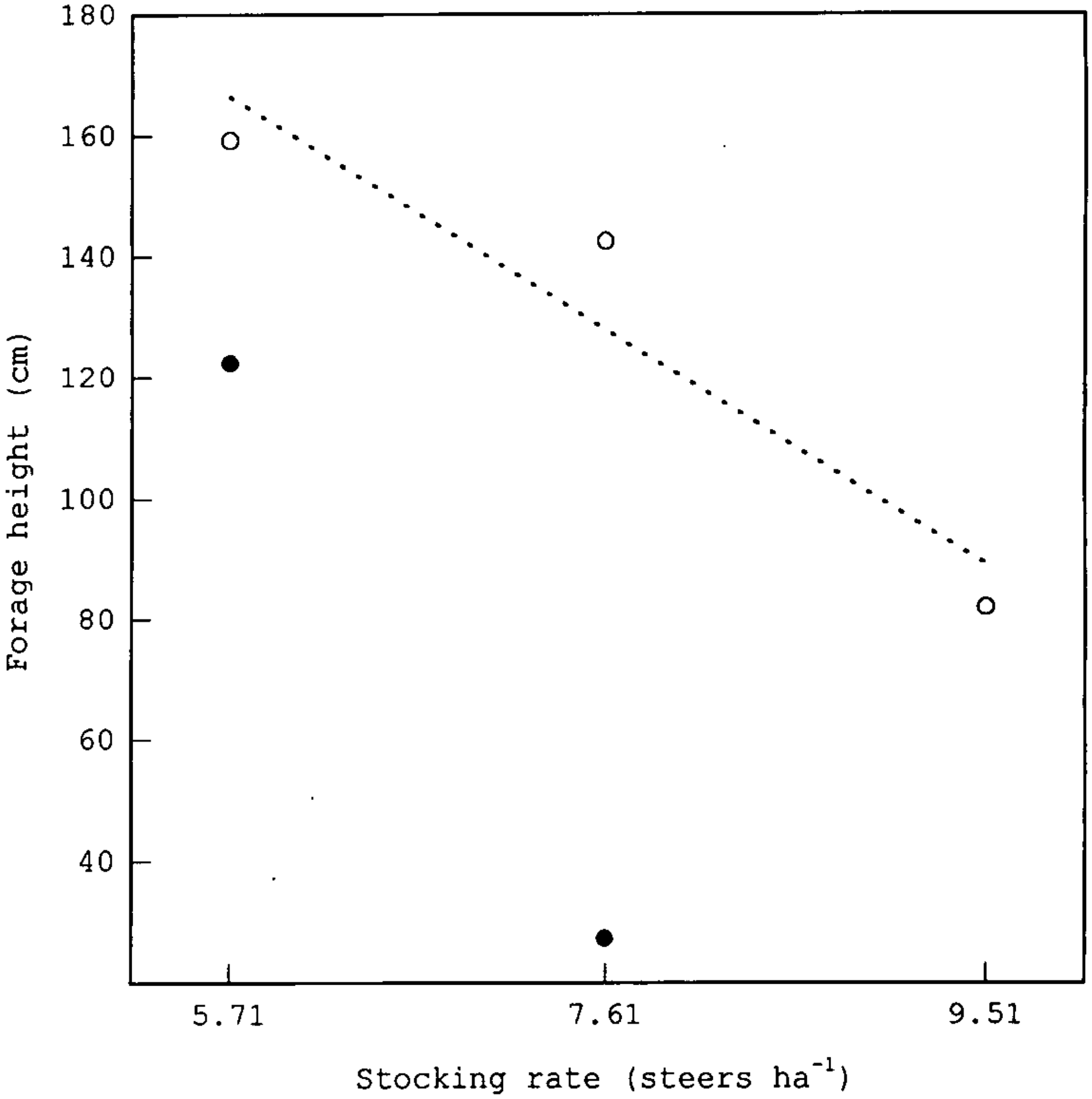

Figure 24. Effect of stocking rate and stocking method on forage height (FH) of Alamo switchgrass grazed by steers for 112 d in 1996, at the Wiregrass Substation, Headland, AL.

● Continuous

--⊙-- Rotational: FH=282.91 - 20.373*SR, r^2=0.75

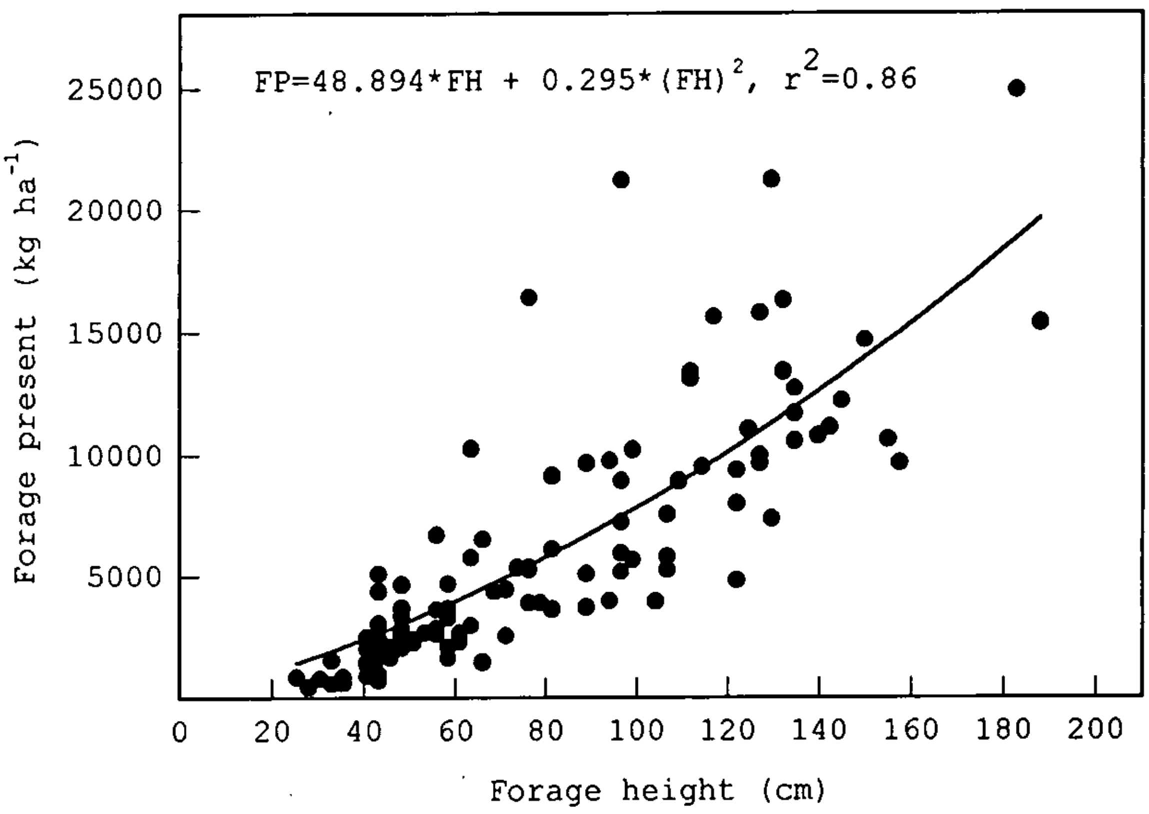

Figure 25. Calibration of forage height (FH) against forage present (FP) of Alamo switchgrass pastures grazed by steers at the Wiregrass Substation, Headland, AL, 1995 and 1996.

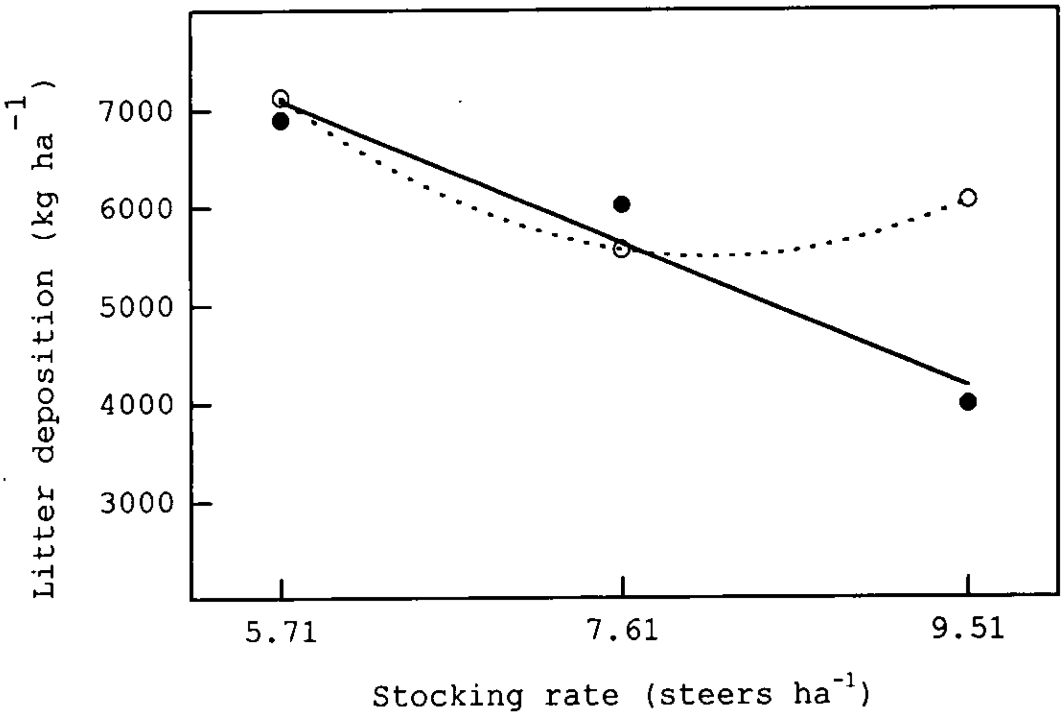

Figure 26. Effect of stocking rate (SR) and stocking method on litter deposition (LD) by Alamo switchgrass grazed by steers at the Wiregrass Substation, Headland, AL, 1995.

—●— Continuous: LD=11475 - 769*SR, $r^2=0.87$

··○·· Rotational: LD=24113 - 4598*SR + 284*SR^2, $r^2=0.58$

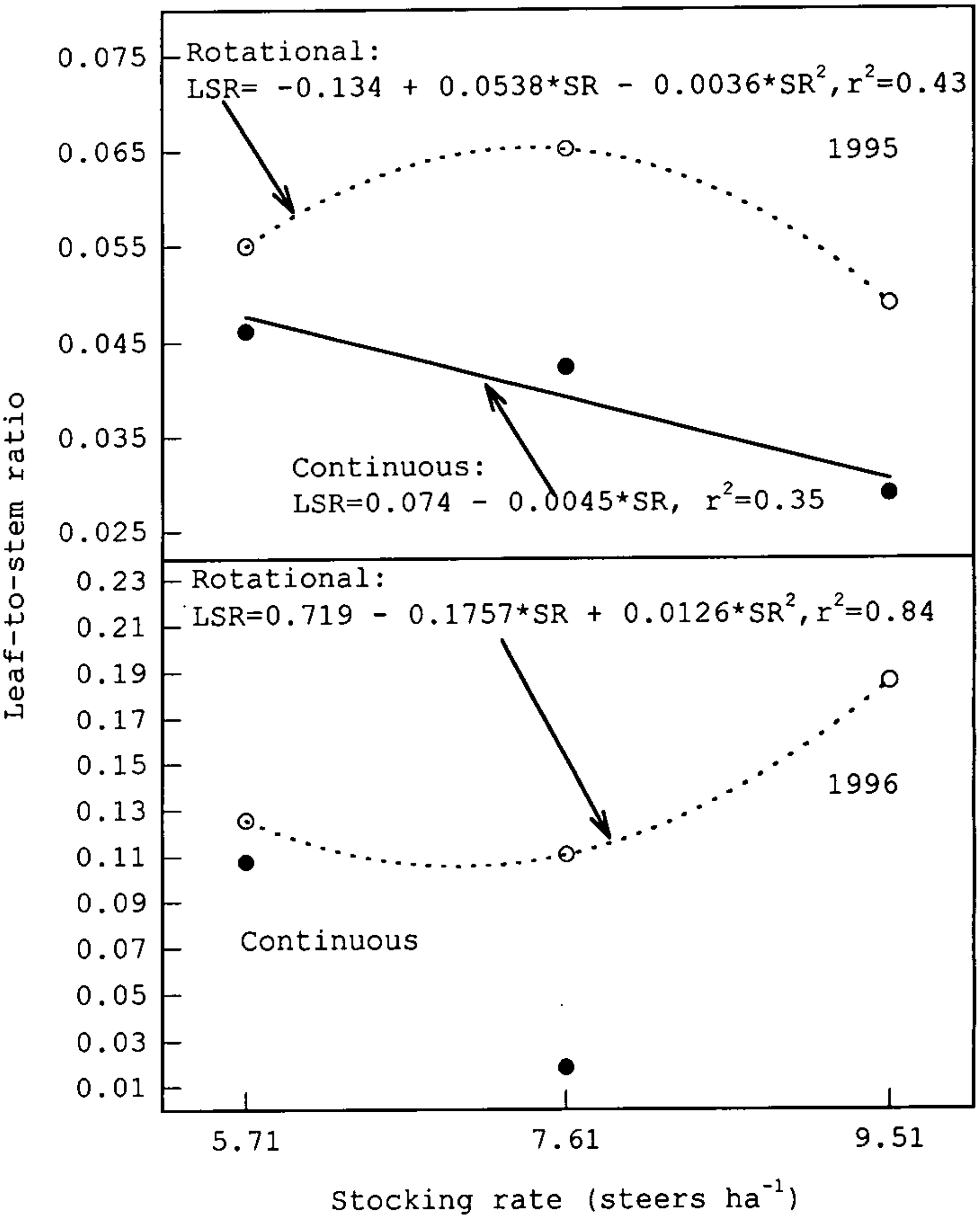

Figure 27. Effects of stocking rate (SR) and stocking method on leaf-to-stem ratio (LSR) of Alamo switchgrass at day 111 (1995) and day 85 (1996), at the Wiregrass Substation, Headland, AL.

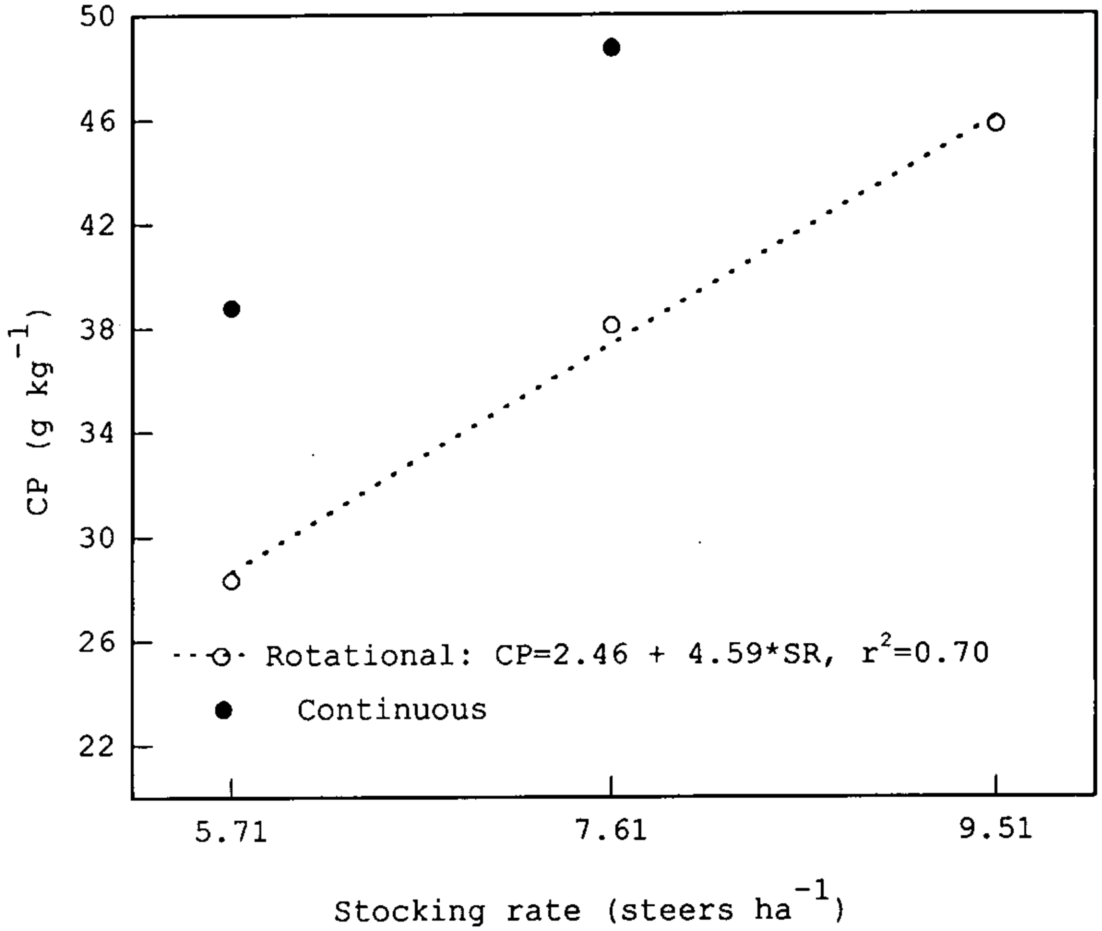

Figure 28. Effects of stocking rate (SR) and stocking method on crude protein concentration (CP) of Alamo switchgrass stems at day 57, of grazing by steers at the Wiregrass Substation, Headland, AL, 1996.

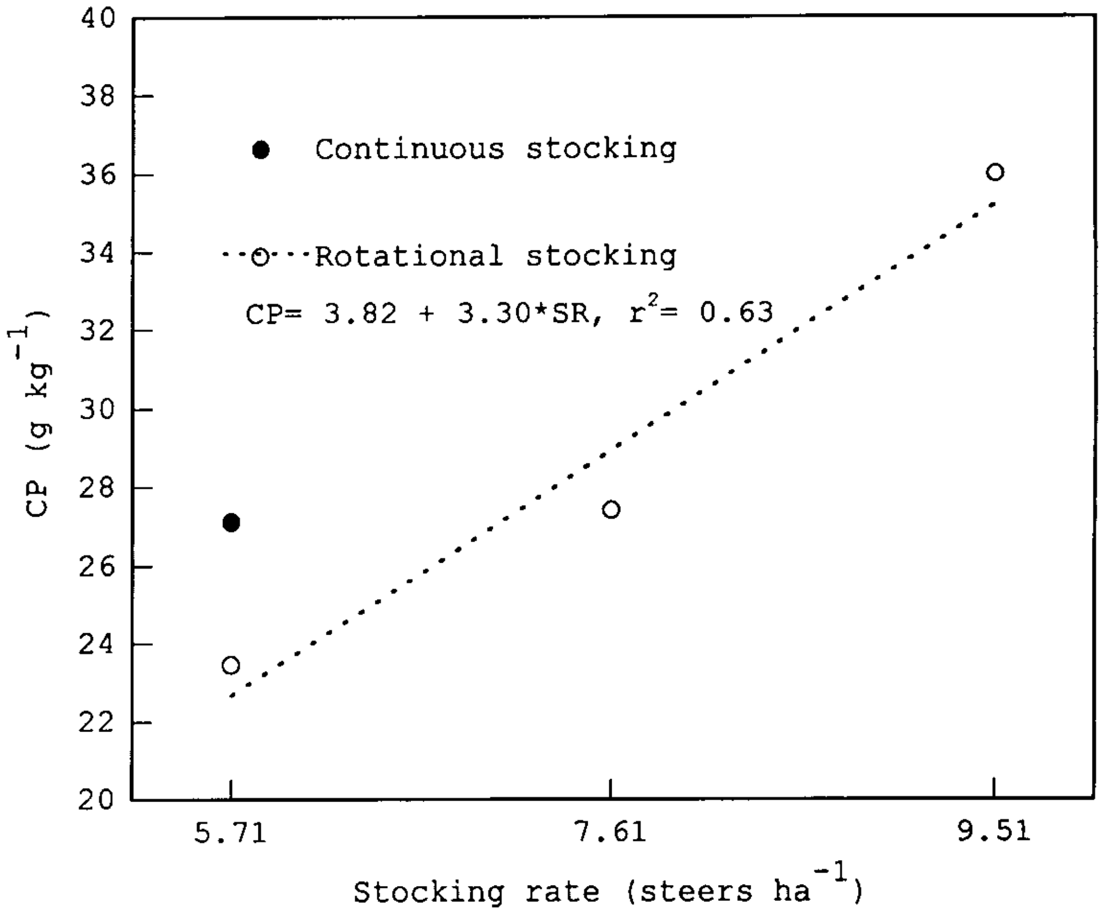

Figure 29. Effect of stocking rate (SR) and stocking method on crude protein concentration (CP) of 'Alamo' switchgrass stems, at day 168 of grazing, at the Wiregrass Substation, Headland, AL, 1996.

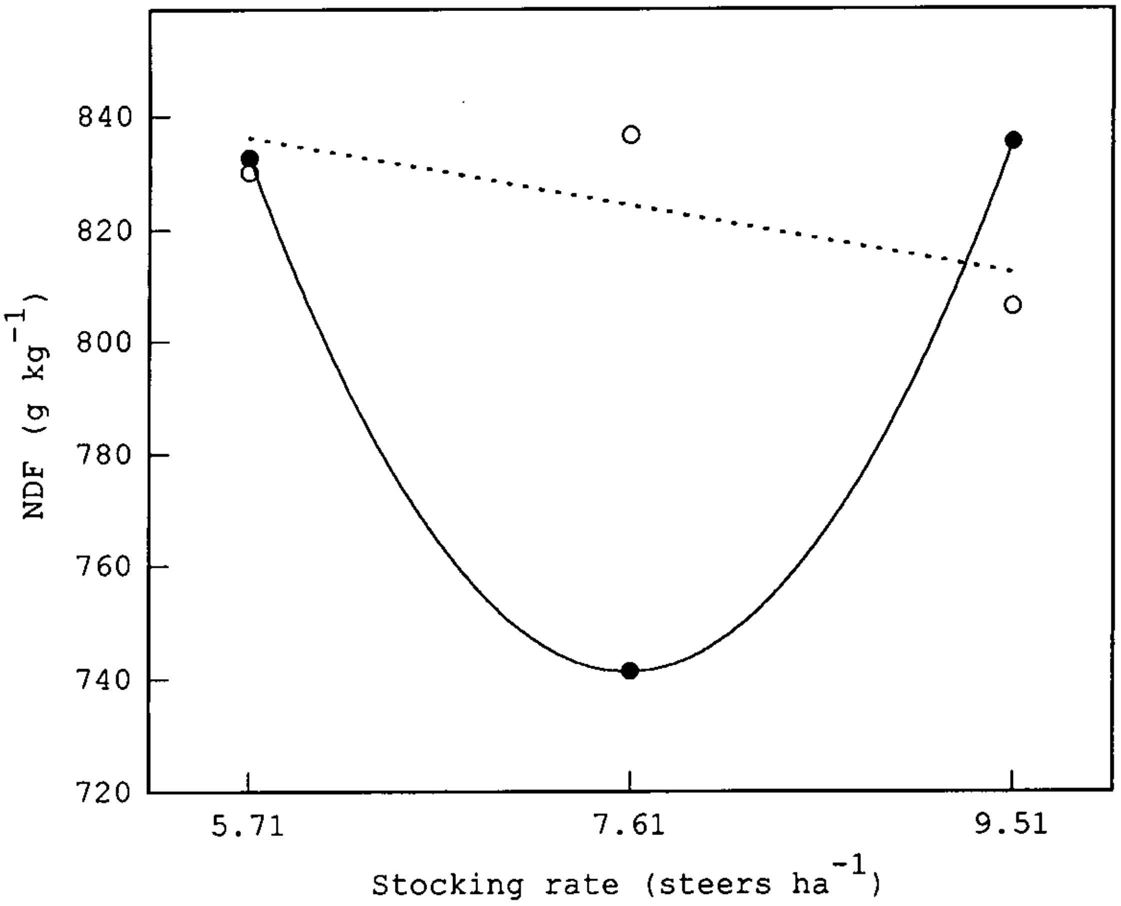

Figure 30. Effect of stocking rate (SR) and stocking method on neutral detergent fiber concentration (NDF) of Alamo switchgrass stems at day 146 of grazing, at the Wiregrass Substation, Headland, AL, 1995.

—○— Continuous: $NDF=2220 - 389*SR + 25.62*SR^2$, $r^2= 0.98$

···●· Rotational: $NDF=872 - 6.28*SR$, $r^2=0.30$

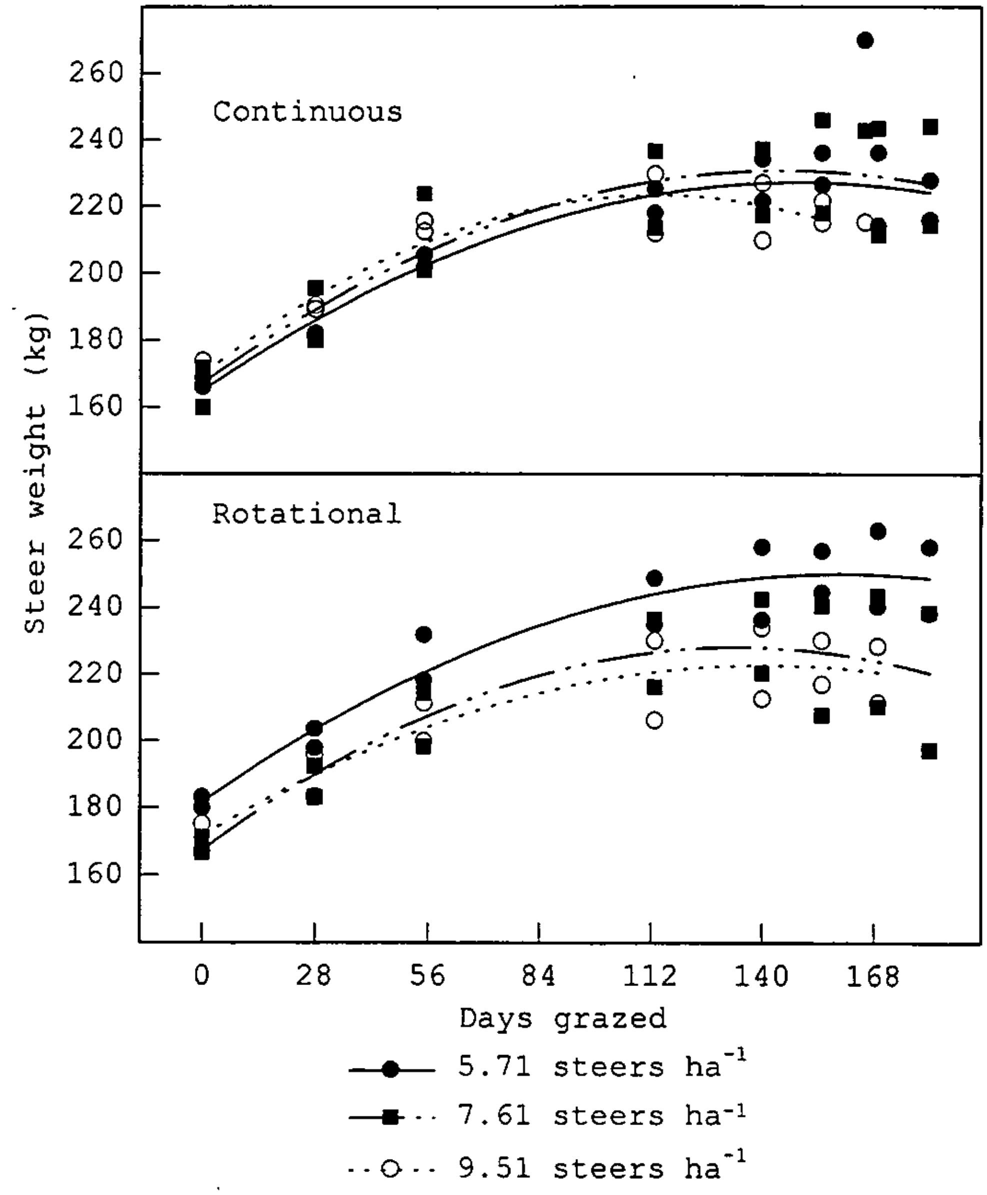

Figure 31. Effect of days grazed (d) on steer weight (W), grazing Alamo switchgrass at the Wiregrass Substation, Headland, AL, 1995.

Stocking method	Stocking rate (Steers ha^{-1})	Regression equations	r^2
Continuous	5.71	$W=164.96 + 0.83*d - 0.0028*d^2$	0.93
Continuous	7.61	$W=167.20 + 0.87*d - 0.0030*d^2$	0.77
Continuous	9.51	$W=169.87 + 0.94*d - 0.0042*d^2$	0.90
Rotational	5.71	$W=181.54 + 0.86*d - 0.0027*d^2$	0.90
Rotational	7.61	$W=167.17 + 0.91*d - 0.0034*d^2$	0.72
Rotational	9.51	$W=171.57 + 0.73*d + 0.0026*d^2$	0.84

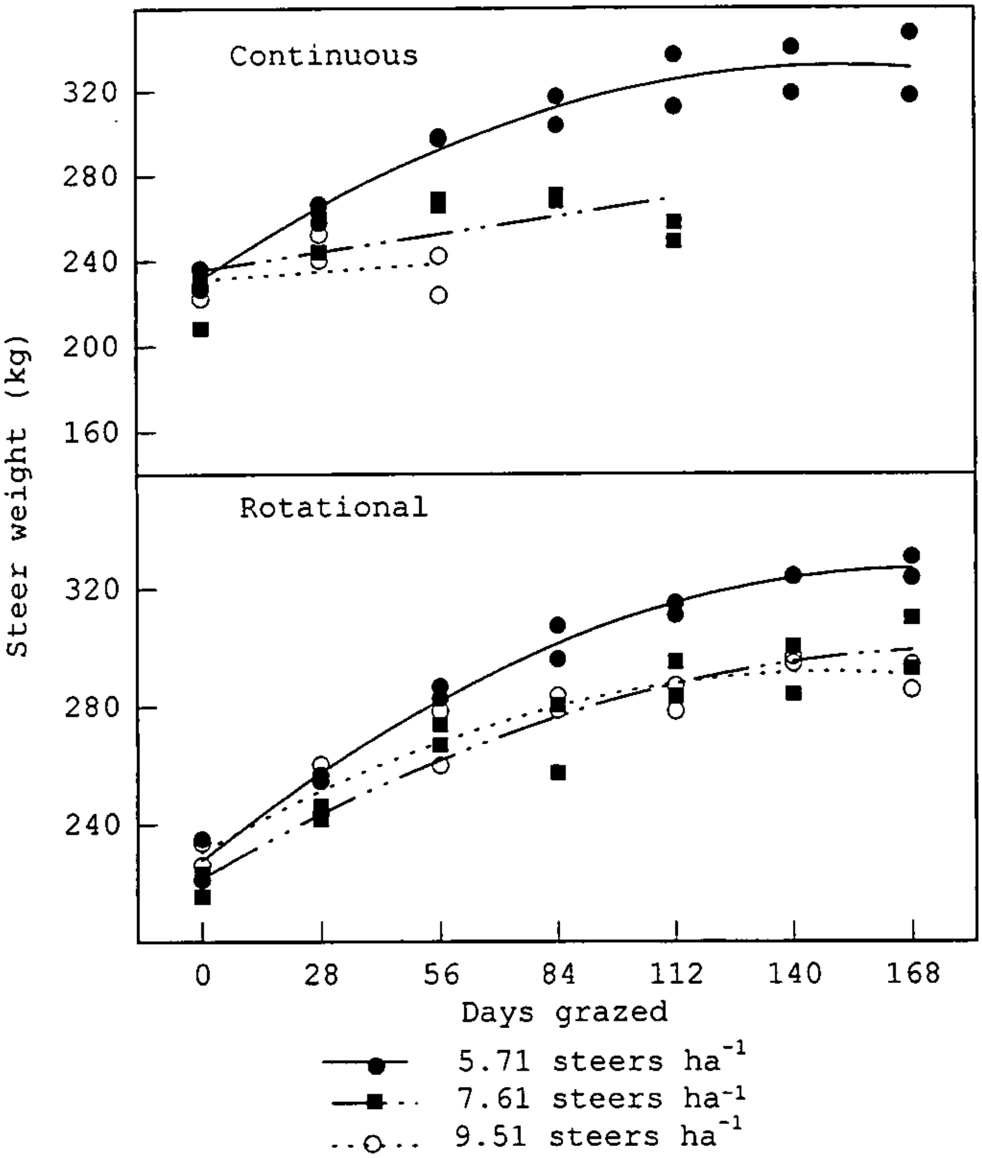

Figure 32. Effect of days grazed (d) on steer weight (W), grazing Alamo switchgrass at the Wiregrass Substation, Headland, AL, 1996.

Stocking method	Stocking rate (Steers ha^{-1})	Regression equations	r^2
Continuous	5.71	$W=231.37 + 1.33*d - 0.0044*d^2$	0.93
Continuous	7.61	$W=235.80 + 0.30*d$	0.39
Continuous	9.51	$W=231.19 + 0.14*d$	0.08
Rotational	5.71	$W=227.70 + 1.16*d - 0.0034*d^2$	0.99
Rotational	7.61	$W=221.56 + 0.85*d - 0.0023*d^2$	0.91
Rotational	9.51	$W=230.54 + 0.82*d - 0.0028*d^2$	0.93

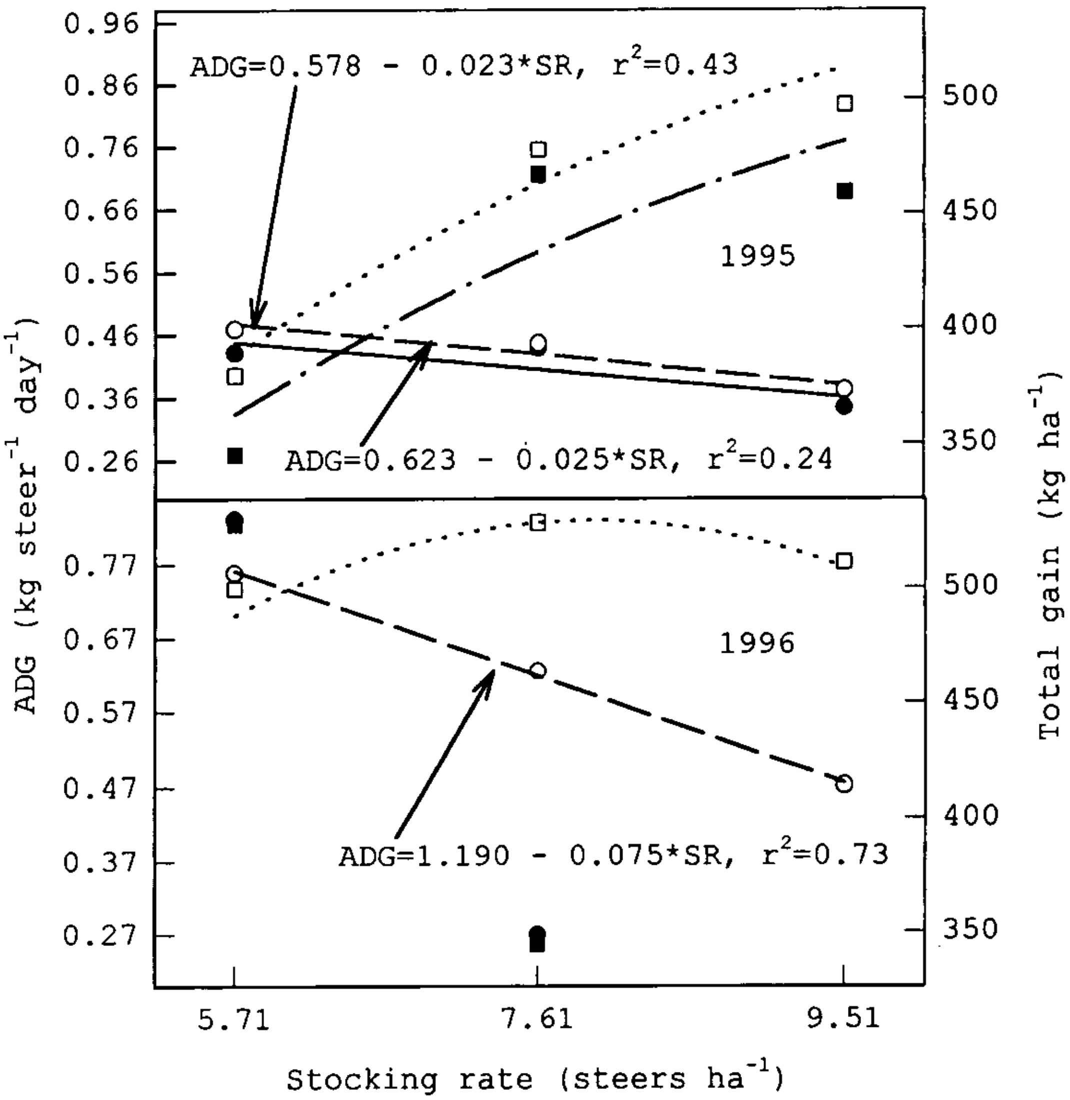

Figure 33. Weight gain of steers as affected by stocking rate (SR) and stocking method, following 140 d (1995) and 112 d (1996) of grazing Alamo switchgrass at the Wiregrass Substation, Headland, AL.

—●— ADG, continuous

—○— ADG, Rotational

—■·· Total gain ha^{-1}, Continuous

···□·· Total gain ha^{-1}, Rotational

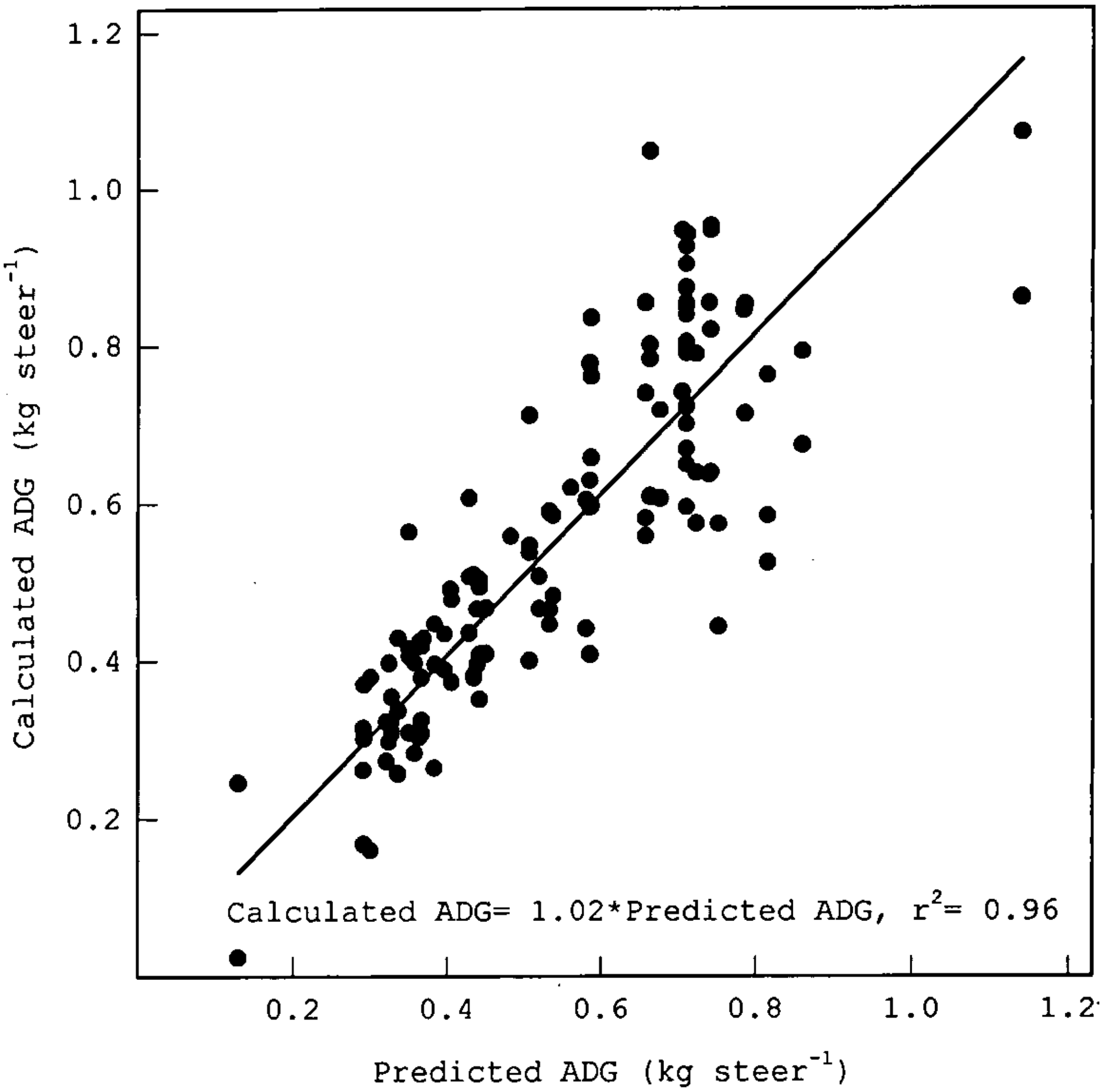

Figure 34. Relationship between ADG predicted from steer growth curves, and ADG from observed steer weights on Alamo switchgrass pastures at the Wiregrass Substation, Headland, AL, 1995 and 1996.

SUMMARY AND CONCLUSIONS

1. Severity of defoliation by lower stubble heights resulted in higher forage yields at the first cut, but in the long-term, yields declined due to depression in regrowth.

2. When individual Alamo switchgrass tillers are transplanted in pots, it appears that the optimum stubble height based on forage yield and morphology is above 25 cm, but this optimum will likely differ in a solid stand under field conditions. The critical stubble height for tiller survival is probably above 5 cm, as no tiller survived following defoliation.

3. It is apparent from this research that both above-ground and below-ground parts, particularly the residual leaf area are vital for regrowth.

4. As with most forages, longer cutting intervals increased forage yield, but decreased quality of regrowth and of total season forage. However, the relative increase in forage yield appeared to be more

important than the corresponding decrease in forage quality. Delaying the first cut by three weeks only affected forage quality of the first cut. First cut yield increased, while regrowth and season yield were affected in different ways, depending mainly on year.

5. Steer performance under season-long grazing of Alamo switchgrass was poor. Stocking rate and stocking method effects were only detectable at the end of the first season, but were carried over to the following season. Under season-long grazing, rotational stocking appeared to have long-term advantages over continuous stocking, particularly at higher stocking rates.

6. Pasture condition deteriorated faster under continuous stocking, and at higher stocking rates. More forage was produced under rotational stocking than under continuous stocking at higher stocking rates, but also more was wasted at 9.51 steers ha^{-1}.

7. Stocking rate and stocking method effects on forage quantity were more evident than on forage quality.

8. Steer growth curves estimated ADG with reasonable precision at any time in the grazing season, and

therefore appeared to be useful for monitoring weight changes over time. This would enable producers to plan supplementation or to sell animals at a targeted date and weight.

9. Producers should examine the economics of the whole enterprise to decide what cutting interval of Alamo switchgrass suits their needs for hay production. Based on forage quantity and quality it is possible to find the optimum cutting interval at which losses in quality are offset by gains in quantity.

10. Other than full-season hay production or full-season grazing, alternative management of Alamo switchgrass should be evaluated: a short early-spring grazing, followed by a hay cut in mid-summer, and a final grazing in early-fall may be a promising option. It appears that Alamo switchgrass is not suited to season-long grazing, but date of grazing initiation was not evaluated in this study and could impact the performance under season-long grazing.

APPENDIX TABLES

Table 1A. Summary of analysis of variance results for dry matter and morphological variables of Alamo switchgrass grown in pots in Experiment 1.

Source	DF	Dry matter and morphological variables						
		First cut yield	Total regrowth	Regrowth 4	Total yield	Leaf number	Leaf-to-stem ratio	Stem length
Blocks	4	***	**	**	***	ns	ns	ns
Height	2	ns	*	**	ns	*	*	ns
Contrasts								
H-Linear	1	*	**	**	*	*	*	ns
H-Lack-of-fit	1	ns	ns	ns	ns	ns	ns	ns
Descriptive Statistics	R^2	0.92	0.89	0.87	0.91	0.63	0.61	0.56
	C.V	33.14	28.06	31.24	24.68	9.00	15.63	28.48
	Mean	6.56	24.72	12.58	31.28	4.21	1.43	42.49

Table 1A. (Continued)

Source	DF	Leaf area	Stubble biomass	Below-ground biomass	Total biomass
Blocks	4	ns	ns	*	***
Height	2	**	**	*	**
Contrasts			**		**
H-Linear	1	*	ns	*	ns
H-Lack-of-fit	1	ns		ns	
Descriptive statistics	R^2	0.89	0.82	0.80	0.92
	C.V	26.87	54.55	37.75	24.59
	Mean	3043.60	10.64	20.60	62.53

*, **, ***= Significant at the 0.05, 0.01 and 0.001 probability levels, respectively, according to the F-test; ns= Not significant at any of the above probability levels

Table 2A. Summary of analysis of variance results for dry matter and morphological variables of Alamo switchgrass grown in pots in Experiment 2.

		Dry matter and morphological variables						
Source	DF	First cut yield	Total regrowth	Regrowth 4	Total yield	Leaf number	Leaf-to-stem ratio	Stem length
Height	2	**	***	**	ns	*	ns	***
Contrasts								
H-Linear	1	**	***	**	ns	*	ns	***
H-Lack-of-fit	1	ns	ns	ns	ns	ns	ns	ns
Descriptive	R^2	0.60	0.77	0.85	0.30	0.55	0.29	0.96
Statistics	C.V	14.86	15.97	24.74	10.92	6.13	22.49	5.62
	Mean	23.62	27.49	5.89	50.88	4.12	1.02	37.31

Table 2A. Continued

Source	DF	Leaf area	Stubble biomass	Below-ground biomass	Total biomass
Height	2	*	***	*	***
Contrasts					
H-Linear	1	*	***	*	***
H-Lack-of-fit	1	*	ns	ns	ns
Descriptive statistics	R^2	0.67	0.94	0.49	0.86
	C.V	9.02	16.14	30.74	9.02
	Mean	4593.80	15.56	28.47	98.31

*, **, ***= Significant at the 0.05, 0.01 and 0.001 probability levels, respectively, according to the F-test; ns= Not significant at any of the above probability levels

Table 3A. Summary analysis of variance results for forage yield and quality of Alamo switchgrass at the E.V. Smith Research Center, Shorter, AL, 1995.

Source	DF	Forage yield and quality variables						
		First cut yield	Reg-rowth yield	Percent regrowth	Season yield	First cut NDF	Reg-rowth NDF	Season NDF
Blocks	2	*	ns	*	*	ns	ns	ns
Date of initial cut	1	***	***	***	ns	***	ns	ns
Cutting interval	2	ns	***	*	***	ns	ns	ns
Date*Interval	2	ns	ns	ns	ns	ns	ns	ns
Contrasts								
Interval-Linear	1	ns	***	**	***	ns	ns	ns
Interval-Lack-of-fit	1	ns	ns	ns	ns	*	ns	ns
Descriptive	R^2	0.94	0.91	0.98	0.88	0.86	0.43	0.51
Statistics	C.V	21.73	12.45	2.45	12.36	3.25	5.25	4.57
	Mean	1985	11789	84.89	13772	663.91	689.96	683.08

Table 3A. (Continued)

Source	DF	First cut ADF	Re-growth ADF	Season ADF	First cut hemicel-lulose	Regrowth hemicel-lulose	Season hemicel-lulose
Blocks	2	ns	ns	ns	ns	ns	ns
Date of initial cut	1	**	ns	ns	*	ns	ns
Cutting interval	2	ns	*	*	ns	ns	ns
Date*Interval	2	ns	ns	ns	ns	ns	ns
Contrasts							
Interval-Linear	1	ns	*	*	ns	ns	ns
Interval-Lack-of-fit	1	ns	*	*	ns	ns	ns
Descriptive	R^2	0.71	0.60	0.63	0.59	0.23	0.38
Statistics	C.V	4.39	4.83	4.06	8.84	6.32	5.66
	Mean	325.93	338.86	335.73	337.98	351.11	347.35

Table 3A. (Continued)

Source	DF	First cut crude protein	Regrowth crude protein	Season crude protein
Blocks	2	ns	ns	ns
Date of initial cut	1	**	ns	ns
Cutting interval	2	ns	***	***
Date*Interval	2	ns	ns	ns
Contrasts				
Interval-Linear	1	ns	***	***
Interval-Lack-of-fit	1	ns	ns	ns
Descriptive	R^2	0.67	0.81	0.83
Statistics	C.V	19.22	11.47	8.81
	Mean	116.30	99.90	104.24

*, **, ***= Significant at the 0.05, 0.01 and 0.001 probability levels, respectively, according to the F-test; ns= not significant at any of the above probability levels.

Table 4A. Summary analysis of variance results for forage yield and quality of Alamo switchgrass at the E.V. Smith Research Center, Shorter, AL, 1996.

Source	DF	Forage yield and quality variables						
		First cut yield	Re-growth yield	Percent regrowth	Season yield	First cut NDF	Re-growth NDF	Season NDF
Blocks	2	ns	ns	ns	ns	ns	ns	ns
Date of initial cut	1	***	ns	***	***	***	ns	ns
Cutting interval	2	ns	***	ns	***	ns	***	***
Date*Interval	2	ns	***	*	**	ns	ns	ns
Contrasts								
Interval-Linear	1	ns	***	ns	***	ns	***	***
Interval-Lack-of-fit	1	ns	**	ns	*	ns	ns	ns
Descriptive	R^2	0.91	0.93	0.95	0.92	0.91	0.83	0.82
Statistics	C.V	27.45	8.80	4.88	9.78	2.04	2.72	2.15
	Mean	2627	8789	78.10	11416	659.17	724.33	714.80

Table 4A. (Continued)

Source	DF	First cut ADF	Re-growth ADF	Season ADF	First cut hemicel-lulose	Regrowth hemicel-lulose	Season hemicel-lulose
Blocks	2	ns	ns	ns	ns	ns	ns
Date of initial cut	1	***	ns	*	***	*	**
Cutting interval	2	ns	***	***	ns	ns	ns
Date*Interval	2	*	ns	ns	ns	*	*
Contrasts							
Interval-Linear	1	ns	***	***	ns	ns	ns
Interval-Lack-of-fit	1	ns	ns	ns	ns	ns	ns
Descriptive	R^2	0.92	0.91	0.92	0.79	0.73	0.73
Statistics	C.V	2.02	3.60	2.84	3.22	2.40	2.08
	Mean	324.82	368.78	362.45	334.35	355.54	352.35

Table 4A. (Continued)

Source	DF	First cut crude protein	Regrowth crude protein	Season crude protein
Blocks	2	ns	ns	ns
Date of initial cut	1	***	ns	ns
Cutting interval	2	ns	***	***
Date*Interval	2	ns	*	*
Contrasts				
Interval-Linear	1	ns	***	***
Interval-Lack-of-fit	1	ns	*	ns
Descriptive	R^2	0.96	0.96	0.96
Statistics	C.V	6.43	6.14	5.30
	Mean	158.17	98.22	106.72

*, **, ***= Significant at the 0.05, 0.01 and 0.001 probability levels, respectively, according to the F-test; ns= not significant at any of the above probability levels.

Table 5A. Summary of analysis of variance results for forage height of Alamo switchgrass, grazed by steers, as affected by stocking rate (SR) and stocking method (SM) at the Wiregrass Substation, Headland, AL, 1995.

		Number of days grazed						
Source	DF	0	28	55	83	111	146	168
Blocks	1	*	ns	ns	ns	ns	ns	ns
Stocking rate	2	ns	**	ns	*	**	**	**
Stocking method	1	ns	**	**	*	**	**	**
SR*SM	2	ns	ns	ns	*	*	ns	ns
Contrasts								
SR-Linear	1	ns	***	*	**	**	**	**
SR-Lack- of-fit	1	ns	ns	ns	ns	ns	ns	ns
Descriptive statistics	R^2	0.80	0.95	0.84	0.88	0.93	0.94	0.93
	C.V.	4.88	3.77	10.09	9.21	8.86	8.53	8.37
	Mean	93.65	103.43	125.93	145.92	140.96	131.02	119.53

*, ** and ***= Significant at 0.05, 0.01 and 0.001 level, respectively, according to the F-test; ns= not significant at any of the above probability levels; ne= not estimable across stocking methods.

Table 6A. Summary of analysis of variance results for forage height of Alamo switchgrass, grazed by steers, as affected by stocking rate (SR) and stocking method (SM) at the Wiregrass Substation, Headland, AL, 1996.

		Number of days grazed						
Source	DF	0	30	58	86	113	141	169
Blocks	1	ns	ns	ns	ns	ns	ns	ns
Stocking rate	2	**	***	*	**	*	ns	ns
Stocking method	1	*	***	**	***	*	ns	ns
SR*SM	2	ns	*	ns	ns	ns	ne	ne
Contrasts								
SR-Linear	1	**	***	*	ne	ne	ne	ne
SR-Lack- of-fit	1	ns	*	ns	ne	ne	ne	ne
Descriptive statistics	R^2	0.92	0.98	0.93	0.97	0.88	0.87	0.76
	C.V	3.53	8.53	22.96	12.19	27.74	16.22	18.81
	Mean	58.83	68.28	90.81	89.10	106.69	118.95	115.71

*, ** and ***= Significant at 0.05, 0.01 and 0.001 level, respectively, according to the F-test; ns= Not significant at any of the above probability levels; ne= Not estimable across stocking methods

Table 7A. Summary of analysis of variance results for leaf-to-stem ratio of Alamo switchgrass, grazed by steers, as affected by stocking rate (SR) and stocking method (SM) at the Wiregrass Substation, Headland, AL, 1995.

		Number of days grazed						
Source	DF	17	28	54	84	111	146	168
Blocks	1	*	ns	ns	*	*	*	*
Stocking rate	2	ns	ns	ns	*	ns	ns	ns
Stocking method	1	ns	ns	ns	ns	**	ns	ns
SR*SM	2	ns	ns	ns	ns	ns	ns	ns
Contrasts								
SR-Linear	1	ns	ns	ns	ns	*	ns	ns
SR-Lack- of-fit	1	ns	ns	ns	*	ns	ns	ns
Descriptive statistics	R^2	0.70	0.68	0.61	0.88	0.90	0.81	0.76
	C.V.	20.66	19.67	42.57	16.89	14.49	29.83	38.42
	Mean	0.44	0.33	0.24	0.07	0.04	0.02	0.01

*, ** and ***= Significant at the 0.05, 0.01 and 0.001 probability levels, respectively, according to the F-test; ns= not significant at any of the above probability levels

Table 8A. Summary of analysis of variance results for leaf-to-stem ratio of Alamo switchgrass, grazed by steers, as affected by stocking rate (SR) and stocking method (SM) at the Wiregrass Substation, Headland, AL, 1996.

		Number of days grazed						
Source	DF	0	29	57	85	112	140	168
Blocks	1	ns	**	ns	*	ns	ns	ns
Stocking rate	2	ns	**	ns	**	ns	ns	*
Stocking method	1	ns	***	**	**	ns	ns	ns
SR*SM	2	ns	*	ns	**	ns	ne	ne
Contrasts								
SR-Linear	1	ns	ne	ne	ne	ne	ne	ne
SR-Lack- of-fit	1	ns	ne	ne	ne	ne	ne	ne
Descriptive statistics	R^2	0.76	0.98	0.92	0.99	0.71	0.78	0.95
	C.V	27.50	6.16	19.50	9.47	85.47	53.55	37.37
	Mean	3.50	0.36	0.20	0.11	0.08	0.07	0.07

*, **, ***= Significant at the 0.05, 0.01 and 0.001 probability levels, respectively, according to the F-test; ns= not significant at any of the above probability levels; ne= not estimable across stocking methods

Table 9A. Summary of analysis of variance results for litter deposition from Alamo switchgrass, grazed by steers, as affected by stocking rate (SR) and stocking method (SM) at the Wiregrass Substation, Headland, AL, 1995.

Source	DF	Result
Blocks	1	**
Stocking rate	2	***
Stocking method	1	*
SR*SM	2	**
Contrasts		
Stocking rate-linear	1	***
Stocking rate-lack-of fit	1	ns
Descriptive Statistics	R^2	0.97
	C.V.	5.14
	Mean	5942

*, **, ***= Significant at the 0.05, 0.01 and 0.001 probability levels, respectively, according to the F-test; ns= not significant at any of the above probability levels.

Table 10A. Summary of analysis of variance results for average daily gain of steers grazing Alamo switchgrass, as affected by stocking rate(SR) and stocking method (SM) at the Wiregrass Substation, Headland, AL, 1995.

		Number of days grazed						
Source	DF	28	55	84	111	140	155	169
Blocks	1	ns	ns	-	ns	ns	ns	ns
Stocking rate	2	ns	ns	-	ns	ns	ns	ns
Stocking method	1	ns	ns	-	ns	ns	ns	ns
SR*SM	2	ns	ns	-	ns	ns	ns	ns
Contrasts								
SR-Linear	1	ns	ns	-	ns	ns	ns	ne
SR-Lack- of-fit	1	ns	ns	-	ns	ns	ns	ne
Descriptive	R^2	0.37	0.45	-	0.63	0.73	0.60	0.52
statistics	C.V	25.03	19.06	-	14.05	13.44	17.92	23.75
	Mean	0.67	0.73	-	0.49	0.42	0.38	0.35

*, **, ***= Significant at the 0.05, 0.01 and 0.001 probability levels, respectively, according to the F-test; ns= not significant at any of the above probability levels; ne= not estimable across stocking methods.

Table 11A. Summary of analysis of variance results for average daily gain of steers grazing Alamo switchgrass, as affected by stocking rate (SR) and stocking method (SM) at the Wiregrass Substation, Headland, AL, 1996.

		Number of days grazed					
Source	DF	28	56	84	112	140	168
Blocks	1	ns	ns	ns	ns	ns	ns
Stocking rate	2	ns	**	**	**	ns	ns
Stocking method	1	ns	ns	ns	ns	ns	ns
SR*SM	2	ns	ns	ns	*	ne	ne
Contrasts							
SR-Linear	1	ns	**	ne	ne	ne	ne
SR-Lack- of-fit	1	ns	ns	ne	ne	ne	ne
Descriptive statistics	R^2	0.56	0.92	0.86	0.94	0.82	0.78
	C.V.	19.51	19.81	15.80	14.33	13.44	17.36
	Mean	0.91	0.78	0.71	0.59	0.59	0.51

*, ** and ***= Significant at the 0.05, 0.01 and 0.001 probability levels, respectively, according to the F-test; ns= not significant at any of the above probability levels; ne= not estimable across stocking methods.

Table 12A. Summary of analysis of variance results for crude protein concentration of Alamo switchgrass grazed by steers, as affected by stocking rate (SR) and stocking method (SM) at the Wiregrass Substation, Headland, AL, 1995.

		Number of days grazed		
Source	DF	84	111	146
Blocks	1	*	**	*
Stocking rate	2	ns	ns	ns
Stocking method	1	ns	**	ns
SR*SM	2	*	ns	ns
Contrasts				
SR-Linear	1	ns	ns	ns
SR-Lack- of-fit	1	ns	ns	ns
Descriptive statistics	R^2	0.86	0.92	0.74
	C.V	9.37	5.37	8.70
	Mean	26.84	22.30	19.68

*, ** and ***= Significant at the 0.05, 0.01 and 0.001 probability levels, respectively, according to the F-test;
ns= not significant at any of the above probability levels;
ne= not estimable across stocking methods.

Table 13A. Summary of analysis of variance results for crude protein concentration of steers grazing Alamo switchgrass, as affected by stocking rate (SR) and stocking method (SM) at the Wiregrass Substation, Headland, AL, 1996.

		Number of days grazed						
Source	DF	0	29	57	85	112	140	168
Blocks	1	ns	ns	ns	ns	ns	ns	ns
Stocking rate	2	ns	ns	ns	ns	ns	ns	ns
Stocking method	1	ns	ns	*	ns	ns	ns	ns
SR*SM	2	ns	ns	ns	ns	ns	ne	ne
Contrasts								
SR-Linear	1	ns	ne	ne	ne	ne	ne	ne
SR-Lack- of-fit	1	ne	ne	ne	ne	ne	ne	ne
Descriptive statistics	R^2	0.91	0.64	0.83	0.66	0.55	0.70	0.96
	C.V.	10.74	8.90	12.81	12.02	23.38	13.03	4.01
	Mean	98.77	59.25	40.04	33.90	40.04	31.58	25.47

*, **, ***= Significant at the 0.05, 0.01 and 0.001 probability levels, respectively, according to the F-test; ns= not significant at any of the above probability levels; ne= not estimable across stocking methods.

Table 14A. Summary of analysis of variance results for neutral detergent fiber concentration of Alamo switchgrass grazed by steers, as affected by stocking rate (SR) and stocking method (SM) at the Wiregrass Substation, Headland, AL, 1995.

		Number of days grazed		
Source	DF	84	111	146
Blocks	1	ns	ns	ns
Stocking rate	2	ns	ns	*
Stocking method	1	ns	ns	*
SR*SM	2	ns	ns	**
Contrasts				
SR-Linear	1	ns	ns	ns
SR-Lack- of-fit	1	ns	ns	**
Descriptive statistics	R^2	0.75	0.49	0.94
	C.V.	0.94	1.25	1.64
	Mean	820.03	833.57	813.66

*, **, ***= Significant at the 0.05, 0.01 and 0.001 probability levels, respectively, according to the F-test.
ns= Not significant at any of the above probability levels.

Table 15A. Summary of analysis of variance results for neutral detergent concentration of steers grazing Alamo switchgrass, as affected by stocking rate (SR) and stocking method (SM) at the Wiregrass Substation, Headland, AL, 1996.

		Number of days grazed						
Source	DF	0	29	57	85	112	140	168
Blocks	1	ns	ns	ns	ns	ns	ns	ns
Stocking rate	2	ns	ns	ns	ns	ns	ns	ns
Stocking method	1	ns	ns	ns	ns	ns	ns	ns
SR*SM	2	ne	ns	ns	ns	ns	ne	ne
Contrasts								
SR-Linear	1	ne	ne	ne	ne	ne	ne	ne
SR-Lack- of-fit	1	ne	ne	ne	ne	ne	ne	ne
Descriptive statistics	R^2	0.64	0.21	0.76	0.35	0.60	0.87	0.85
	C.V.	2.63	2.33	0.82	1.38	2.17	0.88	0.94
	Mean	671.62	774.71	799.45	821.59	813.12	816.01	838.49

*, **, ***= Significant at the 0.05, 0.01 and 0.001 probability levels, respectively, according to the F-test; ns= Not significant at any of the above probability levels; ne= Not estimable across stocking methods

Table 16A. Summary of analysis of variance results for acid detergent fiber concentration of Alamo switchgrass grazed by steers, as affected by stocking rate (SR) and stocking method (SM) at the Wiregrass Substation, Headland, AL, 1995.

		Number of days grazed		
Source	DF	84	111	146
Blocks	1	ns	ns	ns
Stocking rate	2	ns	ns	*
Stocking method	1	*	ns	ns
SR*SM	2	*	ns	**
Contrasts				
SR-Linear	1	ns	*	ns
SR-Lack- of-fit	1	ns	ns	*
Descriptive statistics	R^2	0.89	0.76	0.92
	C.V	1.09	1.71	3.77
	Mean	510.59	518.41	481.74

*, **, ***= Significant at the 0.05, 0.01 and 0.001 probability levels, respectively, according to the F-test; ns= not significant at any of the above probability levels.

Table 17A. Summary of analysis of variance results for acid detergent fiber concentration of steers grazing Alamo switchgrass, as affected by stocking rate (SR) and stocking method (SM) at the Wiregrass Substation, Headland, AL, 1996.

		Number of days grazed						
Source	DF	0	29	57	85	112	140	168
Blocks	1	ns	ns	ns	ns	ns	ns	ns
Stocking rate	2	ns	ns	ns	ns	ns	ns	*
Stocking method	1	ns	ns	ns	ns	ns	ns	ns
SR*SM	2	ne	ns	ns	ns	ns	ne	ne
Contrasts								
SR-Linear	1	ns	ne	ne	ne	ne	ne	ne
SR-Lack- of-fit	1	ne	ne	ne	ne	ne	ne	ne
Descriptive	R^2	1.00	0.49	0.40	0.48	0.66	0.45	1.00
statistics	C.V.	0.25	7.90	1.58	2.95	4.32	2.48	0.16
	Mean	333.51	440.20	491.52	514.38	488.78	503.27	533.13

*, **, ***= Significant at the 0.05, 0.01 and 0.001 probability levels, respectively, according to the F-test; ns= not significant at any of the above probability levels; ne= not estimable across stocking methods.

Table 18A. Summary of analysis of variance results for hemicellulose concentration of Alamo switchgrass grazed by steers, as affected by stocking rate (SR) and stocking method (SM) at the Wiregrass Substation, Headland, AL, 1995.

		Number of days grazed		
Source	DF	84	111	146
Blocks	1	ns	*	ns
Stocking rate	2	ns	ns	ns
Stocking method	1	ns	ns	ns
SR*SM	2	ns	ns	ns
Contrasts				
SR-Linear	1	ns	ns	ns
SR-Lack- of-fit	1	ns	ns	ns
Descriptive statistics	R^2	0.28	0.83	0.55
	C.V.	4.11	1.35	4.99
	Mean	309.71	315.16	331.92

*, **, ***= Significant at the 0.05, 0.01 and 0.001 probability levels, respectively, according to the F-test.
ns= Not significant at any of the above probability levels.

Table 19A. Summary of analysis of variance results for hemicellulose concentration of steers grazing Alamo switchgrass, as affected by stocking rate (SR) and stocking method (SM) at the Wiregrass Substation, Headland, AL, 1996.

		Number of days grazed						
Source	DF	0	29	57	85	112	140	168
Blocks	1	ns	ns	ns	ns	ns	ns	ns
Stocking rate	2	ns	ns	ns	ns	ns	ns	*
Stocking method	1	ns	ns	ns	ns	ns	ns	ns
SR*SM	2	ne	ns	ns	ns	ns	ne	ne
Contrasts								
SR-Linear	1	ns	ne	ne	ne	ne	ne	ne
SR-Lack- of-fit	1	ne	ne	ne	ne	ne	ne	ne
Descriptive statistics	R^2	0.64	0.60	0.88	0.41	0.46	0.69	0.69
	C.V.	5.46	9.76	1.25	4.29	3.23	3.27	2.30
	Mean	338.11	334.51	307.93	307.21	324.33	312.74	305.36

*, **, ***= Significant at the 0.05, 0.01 and 0.001 probability levels, respectively, according to the F-test; ns= not significant at any of the above probability levels; ne= not estimable across stocking methods.

Table 20A. Regression analysis summary for forage height in response to days of grazing Alamo switchgrass at the Wiregrass Substation, Headland, AL, 1995.

Stocking rate	Stocking method	Source of variation	DF	Test results	R^2	Mean	C.V.
5.71	Continuous	Days	1	***	0.77	138.32	11.02
		DayS*Days	1	**			
7.61	Continuous	Days	1	**	0.64	115.07	8.74
		Days*Days	1	ns			
9.51	Continuous	Days	1	ns	0.21	84.90	14.33
		Days*Days	1	ns			
5.71	Rotational	Days	1	***	0.94	141.90	4.86
		DayS*Days	1	***			
7.61	Rotational	Days	1	***	0.91	132.05	6.49
		Days*Days	1	***			
9.51	Rotational	Days	1	ns	0.85	125.29	6.98
		Days*Days	1	***			

*, **, ***= Significant at the 0.05, 0.01 and 0.001 probability levels, respectively, according to the F-test; ns= not significant at any of the above probability levels.

Table 21A. Regression analysis summary for forage height in response to days of grazing Alamo switchgrass at the Wiregrass Substation, Headland, AL, 1996.

Stocking rate	Stocking method	Source of variation	DF	Test results	R^2	Mean	C.V.
5.71	Continuous	Days	1	ns	0.20	91.86	38.30
		DayS*Days	1	ns			
7.61	Continuous	Days	1	ns	0.75	47.41	18.53
		Days*Days	1	**			
9.51	Continuous	Days	1	*	0.98	29.57	9.64
		Days*Days	1	**			
5.71	Rotational	Days	1	***	0.96	126.30	5.98
		DayS*Days	1	***			
7.61	Rotational	Days	1	*	0.73	117.85	15.35
		Days*Days	1	***			
9.51	Rotational	Days	1	ns	0.19	78.18	31.60
		Days*Days	1	ns			

*, **, ***= Significant at the 0.05, 0.01 and 0.001 probability levels, respectively, according to the F-test; ns= not significant at any of the above probability levels.

Table 22A. Regression analysis summary for steer weight in response to days of grazing Alamo switchgrass at the Wiregrass Substation, Headland, AL, 1995.

Stocking rate	Stocking method	Source of variation	DF	Test results	R^2	Mean	C.V.
5.71	Continuous	Days	1	***	0.93	208.37	3.21
		DayS*Days	1	***			
7.61	Continuous	Days	1	**	0.77	211.08	6.27
		Days*Days	1	***			
9.51	Continuous	Days	1	***	0.90	205.25	3.45
		Days*Days	1	***			
5.71	Rotational	Days	1	***	0.90	228.42	3.87
		DayS*Days	1	***			
7.61	Rotational	Days	1	***	0.72	211.87	4.85
		Days*Days	1	***			
9.51	Rotational	Days	1	**	0.84	199.70	1.86
		Days*Days	1	***			

*, **, ***= Significant at the 0.05, 0.01 and 0.001 probability levels, respectively, according to the F-test; ns= not significant at any of the above probability levels.

Table 23A. Regression analysis summary for steer weight in response to days of grazing Alamo switchgrass at the Wiregrass Substation, Headland, AL, 1996.

Stocking rate	Stocking method	Source of variation	DF	Test results	R^2	Mean	C.V.
5.71	Continuous	Days	1	***	0.93	298.38	3.59
		DayS*Days	1	***			
7.61	Continuous	Days	1	ns	0.88	215.50	22.56
		Days*Days	1	ns			
9.51	Continuous	Days	1	ns	0.63	235.08	6.05
		Days*Days	1	ns			
5.71	Rotational	Days	1	***	0.99	290.58	1.60
		DayS*Days	1	***			
7.61	Rotational	Days	1	***	0.91	269.51	3.48
		Days*Days	1	***			
9.51	Rotational	Days	1	***	0.93	271.56	2.54
		Days*Days	1	***			

*, **, ***= Significant at the 0.05, 0.01 and 0.001 probability levels, respectively, according to the F-test; ns= not significant at any of the above probability levels.