# PLANT RESPONSES OF AN *Aeschynomene americana*--*Hemarthria altissima* ASSOCIATION TO GRAZING MANAGEMENT

BY

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To Norman and Lois Sollenberger,

I learned the most
important lessons
from you.

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Limpograss [Hemarthria altissima (Poir.) Stapf et C. E. Hubb.] was selected for use in Florida because it has higher digestibility than do most tropical grasses. Crude protein (CP) concentration of limpograss may be quite low, however. The summer-annual legume aeschynomene (Aeschynomene americana L.) can be high in forage quality, and it has potential for use in association with limpograss. Experiments were conducted in 1983 and 1984 to study aeschynomene establishment in 'Floralta' limpograss sods and to evaluate the effects of grazing management on the aeschynomene-limpograss association.

Small plot studies of aeschynomene establishment suggested that soil moisture at seeding, rainfall within approximately 10 days of seeding, and control of grass competition were most critical in determining success or failure. In 1983 climatic conditions were excellent, and legume germination and emergence were not affected by seedbed preparation or by seeding method. Subsequent legume dry

matter (DM) harvested was greater for seedbed preparation treatments that minimized limpograss competition. Under adverse environmental conditions in 1984, use of higher legume seeding rates (14 vs. 7 kg $ha^{-1}$) and a seeding method which incorporated seeds into the soil (vs. broadcast seeding) produced superior legume stands.

Under grazing, grass stubble height (7.5 or 15 cm) did not affect aeschynomene germination or early seedling survival, but subsequent legume DM accumulation tended to be higher for the 7.5-cm treatment. Continued grazing of the grass until aeschynomene seedlings were 5 cm tall decreased grass competition to the seedlings and improved legume performance. Initiating summer grazing of the association when aeschynomene was 80 (1983) or 60 cm (1984) tall maximized seasonal legume DM accumulation. Earlier grazing (20 cm) resulted in more uniform accumulation of total and aeschynomene DM throughout the season, higher efficiency of grazing, more vigorous legume regrowth, and a trend toward greater total herbage consumption.

Aeschynomene leaves had CP and in vitro digestible organic matter concentrations of 250 g $kg^{-1}$ DM and 700 g $kg^{-1}$ organic matter. Limpograss CP concentration was 25 to 40 g $kg^{-1}$ DM. Forage quality of the association was highest when grazing was initiated at 20 cm. Crude protein concentration of herbage consumed was generally above 70 g $kg^{-1}$ DM when percentage legume in total herbage accumulated was 15% or greater.

Aeschynomene seed production decreased as closure date of fall grazing was delayed. Legume height at initiation of grazing did not affect seed yield $plant^{-1}$.

# CHAPTER I
# INTRODUCTION

The beef cattle industry in Florida has been based on perennial grass pastures for many years. Grass-N systems are highly productive in the humid subtropics, and they require less intensive management than do associations of grasses and legumes (Burton, 1976). Unfortunately, forage quality of tropical grasses is often quite low due to their high cell wall content, low concentrations of digestible organic matter and crude protein (CP), and long retention times in the reticulo-rumen (Wilson and Minson, 1980). Adapted and higher quality grasses and grass-legume associations are needed to increase animal production in the region.

Limpograss [*Hemarthria altissima* (Poir.) Stapf et C. E. Hubb.] is one tropical grass that has been evaluated for use in Florida pastures. It has yield potential comparable to that of other tropical grasses, and cultivar 'Bigalta' has higher concentrations of *in vitro* digestible organic matter (IVDOM) than do most tropical species at similar growth stages (Quesenberry et al., 1978). 'Floralta' limpograss is the most recently released cultivar. It is more persistent and generally higher yielding than Bigalta, but IVDOM concentrations for the two cultivars were not found to be different (Quesenberry et al., 1981). Despite its higher digestibility, average daily gains of animals grazing Floralta have not been superior to those for bahiagrass (*Paspalum notatum* Flugge) (Quesenberry et al., 1984). Euclides (1985) determined that CP concentrations of N-fertilized, continuously stocked Floralta pastures were lower than 50 g $kg^{-1}$ dry matter (DM) during large portions of the grazing season. These results suggest that low CP concentration may be limiting voluntary intake and animal performance on Floralta pastures.

Options for improving the CP concentration of limpograss swards include N fertilization and associating forage legumes with the grass. The cost of N applications to maintain grass CP concentration above 70 g $kg^{-1}$ DM throughout the season is likely to be prohibitive. Forage legumes, though requiring additional management skill, may be a useful alternative.

Aeschynomene (Aeschynomene americana L.) is a widely adapted legume (Hodges et al., 1982) that is high in forage quality (Gildersleeve, 1982) and has potential for use in association with limpograss (Gomes, 1978). Aeschynomene is a summer-annual in Florida, with peak productivity occurring from late July through mid-October. This is a critical time in the state as grass quality is generally quite low and animal performance poor. Use of a legume like aeschynomene may help to avoid the so-called "summer slump."

Little information is available regarding the establishment of aeschynomene into limpograss sods. Grazing management effects on the legume and the legume-grass association also need to be studied. A series of experiments were conducted in 1983 and 1984 to provide additional information on the potential of the aeschynomene-limpograss association. The general objectives of this research were 1) to evaluate aeschynomene establishment in Floralta limpograss sods under a range of management strategies and environmental conditions, 2) to determine the effects of grazing management on legume and sward productivity, pasture botanical composition, and forage quality of the association, and 3) to compare grazing management effects on aeschynomene seed production.

Results of these experiments are presented in a series of four papers (Chapters III through VI) as follows: factors affecting aeschynomene establishment in limpograss (Chapter III), productivity and botanical composition of an aeschynomene-limpograss association in response to grazing management (Chapter IV), forage quality responses of the association to grazing (Chapter V), and aeschynomene seed production responses to defoliation management (Chapter VI).

# CHAPTER II
# LITERATURE REVIEW

The objectives of this review are 1) to provide a thorough overview of the species Hemarthria altissima and Aeschynomene americana, and 2) to supply the reader with the framework from which the dissertation research evolved and on which it was based. No attempt will be made to present a comprehensive discussion of the principles of pasture management, utilization, or quality. Instead, the majority of papers cited will contain information that is directly related to the species and/or problems to be investigated.

## General Description of Limpograss and Aeschynomene

### Limpograss

Limpograss [Hemarthria altissima (Poir.) Stapf et C.E. Hubb.] belongs to the tribe Andropogoneae of the family Poacea. It was introduced into the United States in 1964 from plant collections made in South Africa by Dr. A. J. Oakes of the USDA Plant Introduction Service. The original collection consisted of four plant introductions, three of which have proven to be agronomically useful. These were released in Florida as 'Redalta', 'Greenalta', and 'Bigalta' (Quesenberry et al., 1978). Additional plant exploration (Oakes, 1973) led to the introduction and subsequent release of a limpograss line called 'Floralta' (Quesenberry et al., 1984).

The limpograsses are stoloniferous tropical grasses that perennate in Florida. They exhibit an erect growth habit, and the grass canopy tends to be quite stemmy, with leaves that are generally small and narrow. The inflorescence is a single, spike-like raceme, and more than one raceme may emerge from a node (Quesenberry et al., 1978). Seed set is very low, and all of the limpograsses are established vegetatively.

All cultivars are highly productive in Florida and are well adapted to wet soils (Quesenberry et al., 1978; Quesenberry et al., 1984). Redalta and Greenalta are diploid types with good persistence but low digestibility. Bigalta is a tetraploid with high digestibility (Quesenberry and Ocumpaugh, 1980; Schank et al., 1973), but it does not persist well under intensive grazing management (Pitman et al., 1984). Floralta, also a tetraploid, was specifically selected for persistence under grazing. Like Bigalta it is highly productive, and digestibility values are quite good for a tropical grass (Quesenberry et al., 1981). Unfortunately, N concentrations in Floralta forage may be so low that animal performance is limited (Christiansen, 1982; Euclides, 1985), and this possibility has generated interest in legume-limpograss associations.

## Aeschynomene

A legume that has shown potential for use in association with limpograss is aeschynomene (*Aeschynomene americana* L.). Aeschynomene is of the tribe *Aeschynomenea* of the *Papilionoidae* subfamily of *Leguminosae* (Allen and Allen, 1981). Aeschynomene is native to the subtropics of the Western Hemisphere (Hodges and McCaleb, 1972), and it is indigenous to peninsular Florida (Hodges et al., 1982). No improved cultivars of _A. americana_ have been released in Florida, but the legume is the most widely adapted warm-season legume available for grazing in the state (Hodges et al., 1982).

Aeschynomene is a tall-growing, woody plant that behaves as a summer annual in this region. Fully grown, it reaches heights of 1 to 2 m. The leaves are pinnately compound, with each blade divided into 25 to 60 leaflets. The leaves measure approximately 2 by 8 cm and are sensitive to touch, with the two rows of leaflets folding together when disturbed (Hodges et al., 1982). Aeschynomene exhibits a short-day floral initiation habit (Kretschmer and Bullock, 1980), and flowering of the Florida common ecotypes occurs about 10 September in north-central Florida (Quesenberry and Ocumpaugh, 1981). Flowers are yellow to violet in color, and they develop on axillary racemes (Bogdan, 1977). The seed pods have four to eight segments or joints, and they are generally straight at the upper margin and deeply indented between joints on the lower margin (Bogdan, 1977). Aeschynomene is well adapted to poorly drained soils and occasional standing water (Albrecht et al., 1981; Miller and Williams, 1981). Moore and Hilmon (1969) have observed the legume growing in water 30 to 45 cm deep. In Florida, almost 60% of the soils are subject to seasonal water-logging, so tolerance of such conditions is a very desirable attribute (Allen, 1977).

Until recently aeschynomene was thought to be of minimal agronomic value (Bogdan, 1977). Studies in Florida have shown that the legume can be quite high in forage quality and that maximum forage production occurs during a time when grass quality is too low to sustain high levels of animal performance (Gildersleeve, 1982; Hodges et al., 1982; Ocumpaugh and Dusi, 1981). These findings have spurred interest in overseeding perennial grass pastures with aeschynomene.

## Establishment

Perennial pasture grasses, particularly bahiagrass (*Paspalum notatum* Flugge), are the mainstay of the Florida beef cattle industry. Bahiagrass, though of low forage quality (Euclides, 1985; Moore et al., 1981), is used extensively because it is easy to establish and persists well. Establishment of potential pasture grasses and legume-grass associations must likewise be relatively easy and of low risk. This portion of the review considers some of the important factors affecting limpograss and aeschynomene establishment.

### Limpograss

Schank (1972) reported that seedset occurred in 8 of 11 limpograss introductions evaluated, but in the African introductions seedset averaged only 2%. Because the cultivars released in Florida are African lines, these results indicate that propagation of limpograss will depend upon vegetative plantings.

Ruelke et al. (1979) evaluated Redalta, Bigalta, and Floralta establishment using three different planting techniques. Best results were obtained when sprigging was following by light disking and cultipacking. Bigalta and Floralta were generally superior to Redalta in establishment-year ground cover and dry matter (DM) harvested.

Quesenberry et al. (1984) noted that a bermudagrass [*Cynodon dactylon* (L.) Pers.] sprig planter could also be used to establish limpograss. Using the sprig planter set for a 50-cm row spacing, 750 to 1250 kg of vegetative material were required to plant 1 ha. Moist or wet soil is essential for successful limpograss establishment (Quesenberry et al., 1978), and irrigation may be necessary if summer rains are inadequate. Establishment fertilizer should be low in N and high in P and K to encourage root development without promoting excessive weed growth. Limpograss is slower to establish than digitgrass (*Digitaria* spp.) or bermudagrass, so broadleaf weed control may be necessary (Quesenberry et al., 1984). Despite slower establishment, grazing can be initiated in the spring following planting.

### Aeschynomene

Aeschynomene is a summer annual that is capable of producing large quantities of seed (Hodges et al., 1982; Moore and Hilmon, 1969). Seeds generally remain in the pod, whether they drop from the plant or are combined (Ruelke et al., 1974). Germination of unhulled seed has been reported to be 2 to 6%, with a high proportion of hard seed (Hanna, 1973). Pod removal and mechanical scarification increases germination from around 5% to between 78 (Hanna, 1973) and 98% (Ruelke et al., 1974).

Seed with or without the pod can be obtained commercially, and both types may be useful depending on conditions at seeding. If adequate moisture is available, then naked seed is desirable due to its rapid, uniform germination. If moisture is limiting or is likely to become limiting, seed in the pod or a mixture of the two types should be used. This practice provides a viable reserve should early germinating seedlings die due to environmental stress (Hodges et al., 1982).

Aeschynomene is typically seeded at the onset of the rainy season (1 June to 1 July) in Florida (Hodges et al., 1982). Germination is rapid in warm, moist soils, but seedling growth tends to be relatively slow. Competition from weeds or rapidly growing tropical grasses must be minimized during the establishment period (Hodges et al., 1982).

Less risk is involved when seeding legumes into conventionally prepared seedbeds than into sods because plant cover is destroyed, moisture infiltration and retention may be increased, and seed and rooting environments are improved (Cook and Lowe, 1977). If seeding on a conventionally tilled area, aeschynomene seed should be rolled or disked into the soil to no greater than a 2-cm depth (Hodges and McCaleb, 1972). Cultivated land seeded to aeschynomene should not be grazed from the time of germination until plants reach the desired height for initiation of grazing (Hodges and McCaleb, 1972).

Oversowing of grass sods with legumes, either by sod seeding or surface broadcasting, has potential as a pasture improvement tool in Florida. Establishment costs can be low when compared to conventional tillage and seeding systems (Cook, 1981), but conditions for the establishing seedling may be much more severe (McWilliams and Dowling, 1970). Successful establishment is dependent on the ability of the seedling to compete with the old sod for light, plant nutrients, and moisture (Robinson and Cross, 1960). To favor the developing legume seedling, the seedling's micro-environment and its competitive relationships with other plants must be manipulated by management.

Methods of establishing aeschynomene in grass sods have been evaluated in Florida. Kalmbacher et al. (1978) reported that herbicidal suppression of bahiagrass facilitated aeschynomene establishment and increased yield and crude protein of the grass-legume mixture. Kalmbacher and Martin (1983) achieved excellent aeschynomene establishment by grazing bahiagrass to 3- to 5-cm stubble, drilling legume seed into the sod, and continuing to graze until aeschynomene was 2.5 cm tall. Herbicide applications also were successful in controlling grass competition, but their cost may be prohibitive for beef production systems in Florida. Gomes (1978) evaluated five methods for establishing legumes in Bigalta limpograss. Methods included 1) no tillage, seed broadcast, 2) light disking, seed broadcast, followed by cultipacking, 3) seed broadcast followed by disking and cultipacking, 4) sod seeding with a Zip® seeder, and 5) complete seedbed preparation, seed broadcast, and cultipacking. Despite very high soil temperatures (38°C) in the completely prepared seedbeds, there were more aeschynomene seedlings 6 weeks after planting in this treatment than in any other. Gomes and Kretschmer (1978) suggested that high temperatures scarified depodded aeschynomene seed and increased germination percentage. Gomes (1978) found no differences in subsequent aeschynomene DM harvested due to establishment method. Of five legumes planted with Bigalta, aeschynomene DM production was greatest in the first year. High seed yields enabled aeschynomene to successfully reseed, and stands were excellent in 2 following years.

Methods of stimulating germination and growth of naturally reseeding aeschynomene stands have been investigated. Moore (1978) reported that heavy disking, which involved turning the sod and incorporating surface litter, increased aeschynomene DM harvested four times over that observed with no sod treatment. Tang and Ruelke (1976) obtained higher legume seedling densities and legume DM harvests in burned than in mowed bahiagrass plots. Ruelke et al. (1974) burned an aeschynomene-bahiagrass sod after the legume had produced seed. Compared to mowing the grass sod and removing the residue, burning resulted in more aeschynomene seedlings, greater mixture DM production, greater percentage legume in the mixture, and higher yields of digestible organic matter (DOM). The authors suggested that burning scarified the hard seeds of the legume enabling them to imbibe water and germinate.

## Responses to Clipping and Grazing

Successful growth of legume-grass associations demands a much higher level of management than that required for well-adapted perennial grasses receiving N fertilizer (Burton, 1976). If tropical and subtropical production systems utilizing mixed swards are to be successful, a thorough understanding of plant responses to cutting and grazing managements will be needed. This portion of the review considers the effects of defoliation on forage DM harvested, subsequent plant regrowth, and stand persistence of limpograss and aeschynomene.

### Limpograss

Limpograss is a highly productive forage grass in Florida. Early evaluation showed Bigalta to be more productive than 'Coastcross-1' bermudagrass and a number of digitgrasses (Digitaria decumbens Stent.) (Quesenberry et al., 1978). From 1971 to 1973, three limpograsses were compared with other perennial, tropical grasses (Hodges and Martin, 1975). Redalta and Greenalta out-yielded 'Pensacola' bahiagrass, but they were comparable in yield to 'Coastal' bermudagrass. Bigalta productivity was comparable to that of bahiagrass, but it was lower yielding than bermudagrass. Harvested every 4 to 5 weeks during the wet season, the limpograsses did not persist well, and plots were invaded by weeds in the third year. At Quincy AREC, Redalta, Greenalta, and Bigalta were compared to other tropical forage grasses including Pensacola bahiagrass and Coastcross-1 bermudagrass (Quesenberry et al., 1978). Grasses were cut to 2.5-, 7.5-, and 15-cm stubbles at 4- to 5-week intervals. Bigalta out-yielded Redalta and Greenalta, and limpograss yields were generally higher than those of bahiagrass, but less than those of bermudagrass. Stands of all limpograsses were severely reduced in the second year suggesting that the dry, upland soils of north and west Florida are not well suited for limpograss production.

Ruelke et al. (1976) compared the four limpograss cultivars in a small-plot clipping trial and found Floralta to be the top-yielding genotype. Christiansen (1982) compared Floralta with Bigalta and Redalta at 3-, 9-, and 18-week defoliation frequencies. Forage DM harvested increased with increasing length of rest period, and Floralta was generally either first or second in total DM harvested. In another study, the limpograsses were grazed or clipped at 5-week intervals (Quesenberry et al., 1984). Floralta was generally superior to the other varieties in DM accumulated, and it was more persistent than Bigalta. After 3 years of mob grazing, Ocumpaugh (1982) observed that percent ground cover ranged from 75 to 95 for Floralta compared with 5 to 85 for Bigalta. Christiansen et al. (1981) have suggested that the difference in persistence between Bigalta and Floralta is related to reserve carbohydrate status. Floralta partitions more carbohydrates to stem bases than does Bigalta, presumably giving it an advantage after defoliation.

No grazing recommendations have been published for Floralta. The following are specific suggestions for managing Bigalta. Bigalta should be grazed rotationally to maximize efficiency of utilization and to increase persistence. During the warm season, grazing periods should end when grass stubble is 20 to 30 cm (Chambliss, 1978; Quesenberry et al., 1978). Bigalta maintains a relatively high level of digestibility with increasing maturity (Quesenberry and Ocumpaugh, 1980), so it may be useful as a stockpiled forage. Caution must be exercised, however, as late fall applications of N fertilizer followed by intensive grazing can reduce stands (Chambliss, 1978).

### Aeschynomene

Early plantings of aeschynomene were made in 1952 at the Ona Agricultural Research Center (Hodges et al., 1982). The area was grazed for 2 years, but no management data were found in the literature. Moore and Hilmon (1969) published results from work done in 1963 through 1966. They observed that small stems and leaves of aeschynomene were very palatable to deer and cattle. Heavy browsing of the legume in the establishment year resulted in a more prostrate growth habit and profuse branching.

Tang and Ruelke (1976) evaluated aeschynomene production in response to plant height at cutting (45 or 90 cm) and to stubble height (15 or 30 cm). There were no differences in legume DM harvested due to cutting treatment, but trends favored defoliation at 45 cm. The authors proposed that regrowth of plants cut first at 90 cm was poor due to death of shaded axillary bud sites on the lower stem. Higher stubble heights were recommended to insure persistence when mature plants are cut.

Albrecht and Boote (in press) evaluated the effect of stubble height (9 or 18 cm) on regrowth characteristics of aeschynomene plants that were 60 cm tall or taller when first cut. Virtually all leaf area was removed from the plants at both stubble heights. The 18-cm stubble had more viable axillary buds than did the 9-cm stubble, and this resulted in a more rapid recovery of leaf area and canopy carbon exchange rate for the 18-cm treatment.

Mislevy et al. (1981) compared aeschynomene DM production when plants were cut at 30-, 60-, or 90-cm heights. Highest seasonal DM harvests were from plots cut first at 30 cm, with regrowth cut at 90 cm. Lowest DM production occurred with the 30-cm initial, 30-cm regrowth cut system. High plant mortality was observed in both years when plants were allowed to grow to 90-cm heights before initial harvest. This was attributed to shading and death of axillary buds on lower stems. In general an 8-cm stubble height treatment was more productive than an 18-cm treatment, but it was noted that increasing initial harvest height while maintaining the 8-cm stubble height decreased total yield due to loss of bud sites for regrowth. Branching was most vigorous when plants were cut initially at 30 cm, and regrowth was more rapid for plants cut to an 18-cm versus an 8-cm stubble.

Gildersleeve (1982) evaluated aeschynomene response to grazing. Initiation of grazing occurred when plants were 28, 45, or 54 cm tall. All treatments were subsequently grazed using a 4-week defoliation interval. Plants grazed initially at 28 cm were most persistent and continued to make vigorous regrowth throughout the season. In addition, these plants tended to accumulate more DM over the season than did those where grazing was initiated later. Gildersleeve (1982) noted that early grazing opened up the canopy, decreased light competition, and stimulated axillary bud development and secondary branching.

Recommendations for grazing aeschynomene have been made by a number of authors (Chambliss, 1982; Hodges, 1977; Hodges and McCaleb, 1972; Hodges et al., 1982; Kalmbacher and Mislevy, 1978; Mislevy et al., 1981). It has generally been suggested that grazing be initiated when aeschynomene is 45 to 60 cm in height. Grazing should cease when 75% of leaves and small stems are removed, and remaining stubble should be 15 to 24 cm. Subsequent grazing should be on a rotational basis when regrowth is 45 to 60 cm tall.

Gildersleeve (1982) cautioned that results obtained from clipping should not be the basis for grazing recommendations. Data from clipping trials overestimate DM harvested and underestimate forage quality. Responses observed with aeschynomene under grazing (Gildersleeve, 1982) suggest that current recommendations may need to be revised, but additional evaluation with grazing animals is needed.

## Forage Quality

The most useful definitions of forage quality are expressed in terms of output per animal or voluntary intake of digestible energy (Moore, 1980; Mott, 1959). It is important to note that animal potential and forage availability act independently of forage quality to restrict output per animal (Mott and Moore, 1970). As a result, forage quality can be expressed in terms of output per animal only when 1) the forages being compared are the sole sources of energy and protein, 2) the amount offered exceeds consumption by 5 to 15%, and 3) the animals have potential for production (Moore, 1980; Moore and Mott, 1973).

When these conditions are met, the main factors controlling output per animal (forage quality) are voluntary intake, digestibility, and efficiency of utilization of forage nutrients (Milford and Minson, 1965; Minson, 1980; Moore and Mott, 1973). Voluntary intake varies to a much greater extent than does digestibility (Minson, 1971), and it is considered to be the most important factor accounting for differences in forage quality (Moore and Mott, 1973).

For the purpose of routine laboratory evaluation of forage quality the present method of choice is in vitro determination of digestibility (Moore, 1980). When tropical grasses are being evaluated, N determinations are also important, as N concentrations of 10 to 13 g $kg^{-1}$ DM or lower can limit animal performance (Minson, 1980).

This portion of the review examines limpograss and aeschynomene forage quality responses to a range of management practices. Forage quality in this context includes results from 1) laboratory procedures used to estimate quality, 2) feeding trials in confinement, and 3) large-scale animal production experiments.

Limpograss

Intake of tropical grasses is usually less than that of temperate grasses harvested at similar growth stages (Minson, 1980). This response to tropical species has been associated with their higher concentration of cell wall, lower dry matter digestibility, larger percentage of indigestible cell wall, and longer retention time in the reticulo-rumen (Minson, 1980).

Early screening of limpograss lines showed that Bigalta, a thick-stemmed tetraploid, had higher *in vitro* organic matter digestibility (IVOMD) than did the fine-stemmed diploids, Redalta and Greenalta (Schank et al., 1973). These differences were attributed to stem anatomy as the more digestible cultivar had a lower percentage of vascular bundle per stem cross-sectional area.

Carvalho (1976) showed that Bigalta limpograss was 70 to 180 g *in vitro* digestible organic matter (IVDOM) $kg^{-1}$ OM more digestible than were Pensacola or 'Argentine' bahiagrass for regrowth periods ranging from 1 to 22 weeks. Moore et al. (1981) reported Bigalta IVDOM concentration to be 60 to 80 g $kg^{-1}$ OM higher than that of bahiagrass at 4 or 6 weeks of regrowth. Organic matter intake of Bigalta fed to sheep (expressed as a percent of body weight) was 0.20 to 0.46 units higher than that observed for Pensacola bahiagrass (Moore et al., 1981). Bigalta IVDOM concentration declines more slowly with advancing maturity than does that of many other tropical grasses (Quesenberry et al., 1981). Schank et al. (1973) reported that IVDOM concentration of 5-week regrowth of Bigalta was 684 g $kg^{-1}$ OM, while that of mature plants (first harvested 17 September) was 660 g $kg^{-1}$ OM. *In vitro* digestible organic matter concentration in 14-week Bigalta regrowth was 620 g $kg^{-1}$ OM (Quesenberry and Ocumpaugh, 1980). These responses and Bigalta's relatively good frost tolerance have led to suggestions that it be used as a stockpiled (Chambliss, 1978; Quesenberry and Ocumpaugh, 1980), or off-season forage (Kretschmer and Snyder, 1979; Ruelke and Quesenberry, 1982).

Floralta is also a tetraploid type, and digestibility of Floralta was reported to be similar to (Quesenberry et al., 1981), or somewhat less than (Christiansen, 1982) that of Bigalta. When clipped or grazed at 5-week frequencies, IVDOM concentration for Floralta was 670 and 650 g $kg^{-1}$ OM, respectively (Quesenberry et al., 1984). Under continuous grazing, Floralta IVDOM concentration averaged 100 g $kg^{-1}$ OM higher than that of Pensacola bahiagrass (Euclides, 1985). The IVDOM concentration of esophageal extrusa from the same pastures differed by 50 g $kg^{-1}$ OM.

Animal production trials with Bigalta and Floralta have given mixed results. Centro Internacional de Agricultura Tropical (CIAT) experiments in Colombia have shown continuously grazed limpograss (cultivar name not given) to be superior to *Andropogon gayanus* Kunth., *Cynodon nlemfuensis* Vanderyst, *Brachiaria decumbens* Stapf, and *Brachiaria humidicola* (Rendle) Schweickt, in steer gain $ha^{-1}$ (Tergas et al., 1982). Gain per animal for limpograss was superior to only *A.*

*gayanus* during a 10-month grazing season. Pitman et al. (1984) reported animal gains on Bigalta of 0.71 kg $d^{-1}$ during May at Ona, Florida, but gains were only 0.12 kg $d^{-1}$ during August. Limpograss IVDOM concentration was 46 g $kg^{-1}$ OM lower (526 vs. 572 g IVDOM $kg^{-1}$ OM) in August than it was in May. In the first year of a production trial near Gainesville, Florida, average daily gains from Floralta and Pensacola bahiagrass pastures were 0.35 and 0.33 kg, respectively (Quesenberry et al., 1984). Gain $ha^{-1}$ was twice as great for Floralta because of higher carrying capacity and a longer grazing season. In 3 subsequent years, daily gains on Floralta were similar to or slightly lower than those for bahiagrass, but 100-kg live-weight days $ha^{-1}$ and gain $ha^{-1}$ were greater for Floralta (G. O. Mott and C. S. Jones, unpublished data; Quesenberry et al., 1984). That limpograss failed to produce higher average daily gains than bahiagrass was disappointing in light of the large differences in laboratory estimates of quality.

A possible explanation for the lower than expected gains is low N concentration in limpograss forage. As previously discussed, low N concentration in forages may limit voluntary intake, and intake is the primary determinant of animal production (Minson, 1980). Intake of tropical grasses has been observed to decline rapidly when crude protein (CP) concentration in the consumed feed fell below 70 g $kg^{-1}$ DM (Milford and Minson, 1965; Minson and Milford, 1967). Minson (1980) suggests that for most forage diets the critical CP concentration is in the range of 60 to 80 g $kg^{-1}$ DM.

Carvalho (1976) reported that CP concentration of Bigalta was generally lower than that of digitgrass or bahiagrass. Nine-week regrowth had a CP concentration of 58 g $kg^{-1}$ DM. In work done by S. W. Coleman (Quesenberry et al., 1978), 6-week Bigalta regrowth on organic soils had 114 g CP $kg^{-1}$ DM. Data from north Florida indicated that Greenalta and Bigalta CP concentrations may be low at mid- and late-season (Quesenberry et al., 1978). Results from Hawaii suggest that limpograss CP concentration may be lower than that of other tropical grasses tested (Quesenberry et al., 1978). Bigalta grown during the cool season in south Florida had less than 70 g CP $kg^{-1}$ DM for a range of N fertilization rates from 112 to 336 kg $ha^{-1}$ and cutting intervals from 4 to 12 weeks (Kretschmer and Snyder, 1979). Quesenberry and Ocumpaugh (1980) recommended N supplementation for stockpiled Bigalta, as CP concentration was near or below 70 g $kg^{-1}$ DM. In association with legumes and receiving no N fertilizer, Gomes (1978) reported mean Bigalta CP concentrations of 36, 53, and 37 g $kg^{-1}$ DM for forages harvested on 16 June, 28 July, and 10 Sept. 1977.

Christiansen (1982) reported that the CP concentration of Floralta limpograss was particularly low during mid-summer. Plants harvested in July had CP concentrations ranging from 12 to 47 g $kg^{-1}$ DM depending on cutting frequency (6 to 18 weeks) and N fertilizer rate (0 to 480 kg $ha^{-1}$). Only when 3-week regrowth was harvested were CP concentrations above 70 g $kg^{-1}$ DM. March applications of 75 kg N $ha^{-1}$ resulted in 4- and 6-week Floralta regrowth containing greater than 120 and 80 g CP $kg^{-1}$ DM, respectively (Ruelke and Quesenberry, 1983). By 12 May, 8 weeks after N application, CP concentration was approximately 60 g $kg^{-1}$ DM. Delaying N application to 14 April resulted in forage with approximately 80 g CP $kg^{-1}$ DM on 12 May. Late summer (4 August) application of 75 kg N $ha^{-1}$ increased grass CP concentration to 100 g $kg^{-1}$ DM by 14 September. By 29 September, CP concentration had fallen to just above 40 g $kg^{-1}$ DM. In the second year, 34 kg N $ha^{-1}$ applied in March increased CP to just 70 g $kg^{-1}$ DM, and by 10 May Floralta CP was less than 40 g $kg^{-1}$ DM. In a continuously grazed, N-fertilized Floralta pasture, mean grass CP concentration was 47 g $kg^{-1}$ OM (top 20 cm of sward) from 21 June through 28 October (Euclides, 1985). Mean CP concentration of esophageal extrusa of grazing steers was 58 g $kg^{-1}$ OM. By approximately 20 July, CP concentration of the extrusa was less than 60 g $kg^{-1}$ OM, and it dropped to 50 g $kg^{-1}$ OM during parts of July and August.

Aeschynomene

Thornton and Minson (1973) have observed that legumes generally have a higher voluntary intake than do grasses of the same digestibility. At IVDOM concentrations of 600 g $kg^{-1}$ OM, they reported that mean daily intake of six legume species was 28% greater than that observed for eight grasses (included both $C_3$ and $C_4$ species). Another advantage of legumes is their contribution of N to the animal diet. Minson and Milford (1967) increased voluntary intake of poor quality Pangola digitgrass (40 g CP $kg^{-1}$ DM) by including 100 to 200 g legume $kg^{-1}$ diet DM.

Paul (1951) described the nutritive value of aeschynomene as being comparable to that of alfalfa, but he indicated that it was less palatable. Moore and Hilmon (1969) observed that aeschynomene was readily consumed by both deer and cattle in Florida. Animals selected young plants and the terminal branches and leaves of more mature forage.

Kalmbacher and Mislevy (1978) obtained highest yields of CP and DOM when aeschynomene was first cut at 30 cm and regrowth was cut at 90 cm. Crude protein concentration was 185 g $kg^{-1}$ DM for plants cut initially at 30 cm, and 151 g $kg^{-1}$ DM for those cut first at 90 cm. Spicer et al. (1982) harvested aeschynomene for haylage at late-bloom stage. Crude protein and neutral detergent fiber concentrations were 103 g $kg^{-1}$ DM and 742 g $kg^{-1}$ OM, respectively. Harvesting mature aeschynomene for haylage was determined to be a poor way to utilize the legume forage. When aeschynomene was cut at 30-cm heights throughout the season, CP and IVDOM concentrations averaged 175 g $kg^{-1}$ DM and 700 g $kg^{-1}$ OM, respectively (Mislevy et al., 1981). Delaying initial harvest reduced IVDOM concentration 80 g $kg^{-1}$ OM for each 30-cm increment of legume height. Cutting plants to a stubble of 18 rather than 8 cm increased IVDOM concentration by 20 to 55 g $kg^{-1}$ OM, indicating that higher quality forage was concentrated toward the top of the canopy (Mislevy et al., 1981). Hodges and McCaleb (1972) reported CP concentrations of 241, 213, and 61 g $kg^{-1}$ DM for plant fractions that included the top 15 cm of tall plants, leaves and fine stems only, or coarse stems (3 to 6 mm in diameter), respectively.

Gildersleeve (1982) evaluated aeschynomene under mob grazing. Higher leaf to stem ratios were observed when grazing was initiated at 28 rather than 45 or 54 cm. This was important as animals harvested essentially leaves, seeds, and stems less than 4 mm in diameter. The leaf plus seed fraction averaged 250 g CP $kg^{-1}$ DM and 750 g DOM $kg^{-1}$ OM from August through October (Gildersleeve, 1982). These data indicate that aeschynomene is capable of furnishing high quality forage during a period when perennial grass quality does not meet the needs of a lactating beef cow or a grazing calf (Hodges et al., 1982).

Animal performance has been measured using aeschynomene under a variety of grazing managements. Hodges et al. (1974) seeded aeschynomene into a bahiagrass sod to supplement a digitgrass pasture system. An average of 82% of the cows weaned calves for the system including aeschynomene, and 67% weaned calves when grazing digitgrass alone. Calf weaning weights were similar for the two systems, and average calf production $ha^{-1}$ was slightly higher when using the legume. Hodges (1977) reported yearling heifer daily gains of 0.55 kg when grazing aeschynomene from 26 July to 18 October. Hodges et al. (1976) recorded summer gains of 0.45 kg $d^{-1}$ for a bahiagrass-aeschynomene association compared to 0.26 kg $d^{-1}$ for a bahiagrass-N system. Beef production $ha^{-1}$ was also slightly higher when the legume was included. Summer-annual forages have been evaluated as creep graze for young calves (Ocumpaugh and Dusi, 1981). Aeschynomene was the best forage in both years of the study, and average daily gains were 0.90 kg, compared to 0.68 kg for the bahiagrass control.

## Mineral Status

McDowell et al. (1984) stated that forages can rarely satisfy all mineral requirements of grazing ruminants in warm-climate countries. Concentrations of mineral elements in forages are dependent upon the interaction of a number of factors including soil fertility, plant species, stage of maturity, yield, pasture management, and climate (McDowell et al., 1983). In this portion of the review, data describing the mineral status of limpograss and aeschynomene forages is discussed.

Limpograss

Rojas-Osechas (1985) evaluated the mineral status of 4-, 6-, and 8-week Bigalta regrowth. Potassium, P, Mg, Ca, S, Mn, Fe, and Mo were found to be of adequate concentration for beef cows with average milking ability and body weight of 450 kg. Micronutrients were not included in the grass fertilization program, and Cu, Se, Zn, Co, and Na were deficient. Potassium and Cu were the only minerals to significantly decrease in concentration with increasing maturity. Quesenberry et al. (1978) determined nutrient composition for Greenalta and Bigalta forages which had been fertilized with 55, 24, and 46 kg $ha^{-1}$ of N, P, and K, respectively. Mineral concentrations in limpograss were described as being similar to those of other warm-season perennial grasses. Quesenberry and Ocumpaugh (1982) reported that stockpiled Bigalta limpograss could be used by mature pregnant beef cows without mineral supplementation until late October to early November. After this date, P, K, and Ca may be required if the forage constitutes the total diet.

Aeschynomene

Mineral status of 30- to 90-cm regrowth of aeschynomene has been determined by Kalmbacher et al. (1981). With the exception of Cu, the needs of growing calves and yearlings should be met without supplementation. Potassium concentration declined linearly as initiation of cutting was delayed. Calcium, P, and Mg concentrations showed little response to increasing maturity. Iron concentration increased linearly with plant age while that of Mn decreased. Zinc and Cu concentrations were not affected by delaying cutting. The authors suggest that these data be interpreted with caution as they represent 1 year's results at two locations.

## Fertility Requirements

An adequate treatment of soil fertility relationships to pasture production in the sub-tropics is not possible in the context of this review. The comments that follow are very brief and relate only to the species under consideration.

### Limpograss

Productivity of Floralta limpograss increases with increasing N rates through at least 480 kg N $ha^{-1}$ $yr^{-1}$ (Christiansen, 1982). When cut four times at 9-week intervals, Floralta DM harvested was 5.9, 12.1, and 24.4 Mg $ha^{-1}$ for N rates of 0, 120, and 480 kg $ha^{-1}$. Dry matter harvested was 29.3 Mg $ha^{-1}$ for plots receiving 480 kg N $ha^{-1}$ $yr^{-1}$ and cut every 18 weeks. The high cost of N fertilizer and minimal profit margins for beef producers make high rates of N impractical in Florida pastures. Quesenberry et al. (1984) suggested that 120 kg N $ha^{-1}$ $yr^{-1}$ will provide for high productivity at reasonable cost.

In general, grass pastures on flatwoods soils are fertilized in the spring of the year with approximately 60 kg N, 25 kg P, and 50 kg K $ha^{-1}$ (Dantzman, 1978). Another application of 60 kg N $ha^{-1}$ should be made later in the summer. Sulfur may also be deficient in

Spodosols (Mitchell and Blue, 1981), and if needed, S should be applied at approximately the same rate as P (Dantzman, 1978).

Soil pH of 5.5 to 6.0 is desirable for grass pastures (Dantzman, 1978). Increasing soil pH decreases the availability and uptake of some micronutrients, so applying excess lime is not recommended (McDowell et al., 1983). Iron deficiency has been observed when limpograss was fertilized with high rates of N and defoliated frequently (Quesenberry et al., 1978).

Aeschynomene

The effects of P and K fertilization of aeschynomene on DM and seed production were evaluated by Moore (1978). Treatments in one experiment included N-P-K rates (in kg $ha^{-1}$ $yr^{-1}$) of 0-0-0, 0-20-0, 0-0-74, and 0-20-74. Another study compared rates of 0-0-0, 0-10-37, 0-20-74, and 0-40-148. On a Pompano fine sand (no value given for soil P level), there was no advantage to applying P. Dry matter production doubled with K application of 37 compared to 0 kg $ha^{-1}$ $yr^{-1}$, but there was no yield increase from subsequent K additions. Similar results were obtained for seed production.

A P and lime-rate experiment was conducted at Ft. Pierce on newly cultivated soil with pH of 4.7, Ca concentration of 40 g $kg^{-1}$, and P concentration of 1 g $kg^{-1}$ (extractant not given) (Hodges et al., 1982). In 2 years of observations, 2.0 Mg lime $ha^{-1}$ before seeding (first year only) and 60 kg P $ha^{-1}$ $yr^{-1}$ resulted in legume DM harvested of 5.6 Mg $ha^{-1}$ $yr^{-1}$. An additional 1.0 Mg $ha^{-1}$ of lime with no increase in rate of P, increased aeschynomene production 0.9 Mg $ha^{-1}$ $yr^{-1}$. Plots receiving 0.2 Mg lime $ha^{-1}$ and 20 kg P $ha^{-1}$ $yr^{-1}$

yielded just 13% as much as those receiving 3.0 Mg $ha^{-1}$ of lime and 60 kg P $ha^{-1}$ $yr^{-1}$. Reporting on the same study, Kretschmer and Snyder (1981) noted that aeschynomene receiving 60 versus 20 kg P $ha^{-1}$ $yr^{-1}$ produced 2.9 Mg $ha^{-1}$ of additional DM over a 2-year period.

Recommendations for sustained aeschynomene production include liming to pH 5.5 to 6.0 (Hodges et al., 1982). Hodges et al. (1982) suggest that P and K should be applied at rates of 15 and 56 kg $ha^{-1}$, despite responses to higher levels as described above. Soils not routinely receiving micronutrients should have a micronutrient mixture applied (22 kg $ha^{-1}$) that is similar in composition to F-503 Oxide (Hodges et al., 1982).

Land not previously cultivated should be limed to pH 5.5 to 6.0, and 120 kg $ha^{-1}$ of $P_2O_5$ and $K_2O$ should be applied prior to seeding (Hodges et al., 1982). Micronutrients also may be needed, but it has been observed that soils producing good bahiagrass supply enough micronutrients for aeschynomene, with the possible exception of B (Hodges and McCaleb, 1972).

## Disease and Pest Problems

### Limpograss

No major diseases have been associated with limpograss in Florida (Quesenberry et al., 1984). Both *Pythium* and *Fusarium* root rot were diagnosed on Bigalta grown on an organic soil, but these diseases have not been significant problems (Quesenberry et al., 1978).

Insect and nematode damage have also been minimal. The armyworm complex (family *Noctuidae*) that attacks many grasses in Florida can cause severe, but generally very isolated damage (Quesenberry et al., 1984). Carvalho (1976) observed that there was less insect feeding on Bigalta than there was on bahiagrass or digitgrass. Greenalta and Floralta were found to be less susceptible to the yellow sugar-cane aphid (*Sipha flava* Forbes) than was Pangola digitgrass (Oakes, 1978). Boyd and Perry (1969) reported that yields of Redalta, Greenalta, and Bigalta were less than those of most tropical grasses when grown in a sandy soil that was infested with sting nematodes (*Belonolaimus longicaudatus* Rau). Floralta had significantly less tolerance to sting nematode than the most tolerant *Hemarthria* genotype, but it was not different from Bigalta and Redalta in tolerance (Quesenberry and Dunn, 1978). These findings suggest that limpograss should not be planted on sandy soils infested with sting nematode (Quesenberry et al., 1978). Damage from this nematode does not seem to be a problem on flatwoods soils, possibly due to high water levels during the rainy season (Quesenberry et al., 1978).

### *Aeschynomene*

Sonoda and Lenne (1979) have compiled a bibliography on diseases of the genus *Aeschynomene*. Viral diseases of the genus include tobacco streak virus and legume little leaf disease. Fungal pathogens include the genera *Uredo*, *Colletotrichum*, *Cercospera*, and *Physoderma* (Kretschmer and Bullock, 1980). *Colletotrichum* spp. (anthracnose) has been isolated from *Aeschynomene* spp. at Ft. Pierce, but there was no clear relationship between given species and levels of resistance.

Armyworm defoliation of aeschynomene has been reported at Ona (Kalmbacher et al., 1981). Kretschmer and Bullock (1980) have documented leaf and stem feeding of aeschynomene by a looper [Selenis monotropa (Grote)]. Velvetbean caterpillar (Anticarsia gemmatalis Hubner) has also been found feeding on aeschynomene (Moscardi, 1979), but these larvae are not often a severe problem as they succumb to a fungal disease [Nomuraea rileyi (Farlow) Samson] in September and October. Kretschmer and Bullock (1980) also observed moderate damage due to a microlepidopteran leaf binder. A major pest to legume seedlings in grass sods is the snail (Kalmbacher et al., 1979). Burning the sod after dessication with paraquat was found to kill 98% of the snail population.

Rhoades (1980) and Kretschmer et al. (1980) indicated that Florida common aeschynomene was resistant to southern rootknot nematode. Pasley (1981) found both susceptible and resistant ecotypes in A. americana, and the author cautioned that all sources of Florida common aeschynomene may not be supplying resistant material.

## Effects of Defoliation on Seed Production

### Limpograss

As described earlier in the review, seed set on limpograss lines is quite low (Schank, 1972), and propagation in Florida has depended upon vegetative plantings.

### Aeschynomene

Aeschynomene is capable of producing large quantities of seed (Hodges et al., 1982; Moore and Hilmon, 1969). This is a potentially important trait for an annual, but Humphreys (1979) has indicated that the effects of grazing and mowing on flowering and seed production of tropical pasture species are not well understood.

Loch and Humphreys (1970) reported that defoliation of Stylosanthes humilis H.B.K. at floral initiation, flower appearance, or advanced flowering sharply reduced seed production. The main effect of defoliation was to reduce the proportion of florets setting seed. This happened because flowering time was delayed, and inflorescences from defoliated plants matured under conditions of decreased temperature and radiation. In another experiment, seed production of Stylosanthes guyanensis was reduced if grazing continued up to the time of floral initiation (Loch et al., 1976). There were no differences in seed production, however, between an undefoliated control and plants that were defoliated during vegetative growth. Wilaipon and Humphreys (1976) reported a 61% increase in seed yield, over that observed in an undefoliated control, when Stylosanthes hamata (L.) Taub. was defoliated at early flowering. In this situation, the legume was grown in association with a tall grass, and grazing decreased grass competition. Increased branching and more bud sites for inflorescence development were also attributed to defoliation.

Gildersleeve (1982) evaluated aeschynomene seed production response to plant density and to plant height when grazing was initiated. Higher plant density resulted in increased seed yield, but seed yield decreased as initiation of grazing was delayed. She concluded that early grazing removed apical dominance, encouraged axillary regrowth, and provided more sites for inflorescence development.

Pitman and Kalmbacher (1983) evaluated aeschynomene seed production under grazing. Seed yield was 27.7, 17.7, and 12.8 g $m^{-2}$ when grazing was terminated on 2 September (vegetative growth), 8 October (first flower), or 4 November (cessation of plant growth), respectively.

# CHAPTER III
# FACTORS AFFECTING THE ESTABLISHMENT OF AESCHYNOMENE IN FLORALTA LIMPOGRASS SODS

## Introduction

Many of the tropical grasses adapted to Florida are low in forage quality during most of the growing season, and performance of grazing animals may be limited as a result. Highly productive and better quality forage species and associations must be developed in order to increase animal production.

Limpograss [*Hemarthria altissima* (Poir.) Stapf et C. E. Hubb.] has shown potential for use in Florida as a forage. A persistent and productive limpograss variety with higher *in vitro* organic matter digestibility (IVOMD) than many tropical grasses at comparable growth stages was recently released as 'Floralta' (Quesenberry et al., 1984). Carrying capacity (animal days $ha^{-1}$) of Floralta pastures has consistently been greater than that of bahiagrass (*Paspalum notatum* Flugge) pastures, but average daily gain was similar for the two grasses (Quesenberry et al., 1984). There is evidence to suggest that low N concentration in limpograss forage may be the major factor limiting animal gains (Euclides, 1985).

To address the problem of low N content, forage legumes have been evaluated in association with limpograss (Gomes, 1978). A legume that has shown potential for use with Floralta is aeschynomene (*Aeschynomene americana* L.). When well managed, aeschynomene can provide a high quality forage for the grazing animal (Gildersleeve, 1982; Sollenberger et al., 1985), and like limpograss, aeschynomene is well adapted to poorly drained soils (Albrecht et al., 1981; Miller and Williams, 1981).

Aeschynomene has been successfully established in bahiagrass sods with the aid of herbicides, burning, and grazing for control of grass competition (Kalmbacher et al., 1978; Kalmbacher and Martin, 1983). Aeschynomene is typically seeded after the onset of summer rains in Florida (Hodges et al., 1982), but this limits the productive period of the legume. Development of management strategies to aid legume establishment in limpograss sods is of importance, and information regarding the potential of spring seeding of aeschynomene is also needed.

Experiments were conducted in 1983 and 1984 to evaluate aeschynomene-Floralta limpograss associations. The objectives of this research were to compare the effects of seeding rates, seeding dates, types of seedbed preparation, and seeding methods upon legume establishment, legume and total dry matter (DM) and N production, and sward botanical composition.

## Materials and Methods

The research was carried out during 1983 and 1984 at the University of Florida's Beef Research Unit located northeast of Gainesville, Florida. The site was a 10- by 50-m block of Floralta that had been established in 1978. The soils were of the Wachula series (sandy, siliceous, hyperthermic Ultic Haplaquod), a poorly drained flatwoods type. Prior to initiating the experiment in 1983, soil pH at the site was 5.6, and Mehlich I extractable P and K levels were 9 and 40 mg $kg^{-1}$, respectively. Guided by soil test results, P and K were broadcast applied at rates of 25 and 90 kg $ha^{-1}$ in 1983 and 45 and 165 kg $ha^{-1}$ in 1984.

In 1983, four establishment methods and two legume seeding rates were arranged as a complete factorial set of treatments in six replications of a randomized block design. The methods of establishment were 1) no disturbance of the grass sod and broadcast seeding of the legume (broadcast), 2) light disking, broadcast seeding, and cultipacking (disk), 3) application of 1,1'-dimethyl-4,4'-bipyridinium ion (paraquat) at 0.56 kg $ha^{-1}$ (active ingredient) followed by broadcast seeding (herbicide), or 4) seeding with a Powr-till® seeder (seeder). Seeding rates were 7 or 14 kg $ha^{-1}$ of dehulled seed that had been inoculated with rhizobia from the cowpea group. Plot size was 2 by 4.5 m.

Paraquat was applied to appropriate plots on 2 June 1983. Tillage and seeding operations were carried out the following day. Grass height at seeding was approximately 15 cm. Eighty millimeters of rain fell within 7 days of seeding, and mean daily high and low temperatures during the period were 30 and 18°C, respectively. Stand counts of legume seedlings were made 10, 20, 30, and 60 days after seeding. Four, 20- by 30-cm areas were permanently marked in each plot, allowing the same quadrats to be counted at each date.

A single harvest of all plots was taken on 22 Sept. 1983. A 1- by 4-m area was cut to an 8-cm stubble height using a Carter flailtype harvester. The cut forage was weighed wet, and a 1-kg subsample was dried at 60°C to determine percent dry matter. Botanical composition of harvested DM was determined by hand separation of freshly harvested herbage. The sample for separation was obtained using a sickle-bar mower to cut a 5- to 8-cm strip along the harvested portion of each plot. Separated forage was dried at 60°C, weighed, and ground to pass a 1-mm screen.

Legume seeding rates and only the broadcast and disk establishment methods used in 1983 were evaluated again in 1984. Four seeding dates, 1 April, 20 April, 10 May, and 20 June were also compared. The design used was a split-plot with seeding dates as the whole plot treatment, and all treatments were replicated three times.

Soil moisture and temperature at the soil surface (to 2 cm) were determined three times a week for 3 weeks following each seeding date in 1984. Two-gram soil samples were weighed wet then dried overnight at 105°C to determine percent moisture. Soil temperature was measured with a mercury-bulb thermometer. Although early morning determinations may have been more useful, logistical constraints required that sampling and temperature readings be taken between 1300 and 1400 h. Values reported are seeding date means over methods, rates, and replications.

Legume seedling counts were made at 10, 20, and 30 days after each seeding date according to the procedure described for 1983. All plots were harvested on 12 July and 3 Oct. 1984. A 1- by 4-m area was cut to a 12- (12 July) or 8-cm (3 October) stubble using a sickle-bar mower. Cut forage was collected and weighed immediately. Subsampling for percent DM determinations and methods for determining botanical composition were the same as in 1983.

After grinding, legume and grass samples were analyzed for N. Forages were digested using a modification of the aluminum block digestion procedure of Gallaher et al. (1975). Sample weight was 0.3 g, catalyst used was 3.2 g of 9:1 $K_2SO_4$:$CuSO_4$, and digestion was conducted for 4 h at 400°C using 10 ml $H_2SO_4$ and 2 ml $H_2O_2$. Ammonia in the digestate was determined by semiautomated colorimetry (Hambleton, 1977). Crude protein (CP) was calculated as N X 6.25.

## Results

### Germination and Seedling Development: 1983

Legume germination and emergence occurred within 72 hours following seeding in 1983. Legume seedling number was not affected by establishment method at any of the count dates ($P \geq 0.15$), but there were approximately twice as many seedlings for the 14 compared to the 7 kg $ha^{-1}$ legume seeding rate on all dates ($P < 0.01$, Table A-1). Plant populations declined over time for both rates. For example, seedling number for the high rate decreased from an average of 120 $m^{-2}$, 10 days after seeding, to 90 $m^{-2}$ at the 60-day count.

### Dry Matter and N Harvested: 1983

Rainfall was well distributed throughout the 1983 growing season (Table 3.1) and aeschynomene was approximately 1.5 m tall by harvest date. There was no establishment method x seeding rate interaction ($P \geq 0.28$) for any response variable, so main effects are considered

Table 3.1. Rainfall data for 1983 and 1984 recorded at the Beef Research Unit, northeast of Gainesville, Florida.

| Month | 1983 | 1984 | 70-year† mean |
|---|---|---|---|
| | mm | | |
| Jan. | 82 | 35 | 72 |
| Feb. | 112 | 107 | 94 |
| Mar. | 182 | 92 | 108 |
| Apr. | 163 | 82 | 77 |
| May | 80 | 122 | 90 |
| June | 141 | 95 | 173 |
| July | 94 | 258 | 204 |
| Aug. | 194 | 62 | 210 |
| Sept. | 190 | 67 | 144 |
| Oct. | 61 | 29 | 93 |
| Nov. | 109 | 81 | 49 |
| Dec. | 192 | 16 | 74 |
| Total | 1600 | 1046 | 1388 |

†Seventy-year means are for Gainesville as recorded by the University of Florida Agronomy Department.

directly. Total DM harvested was affected by method of establishment ($P < 0.01$) but not by legume seeding rate ($P = 0.30$). Broadcast and seeder treatments maximized grass and total DM harvested, and disk was superior to herbicide (Table 3.2). Grass DM harvested was not affected by legume seeding rate ($P = 0.53$). Legume DM harvested and percentage legume in total DM were affected by establishment method ($P < 0.01$), with the herbicide treatment resulting in maximum legume performance (Table 3.2). There was a strong trend favoring the 14 kg $ha^{-1}$ seeding rate ($P = 0.08$), as legume DM harvested was 0.7 Mg $ha^{-1}$ higher (5.8 vs. 5.1 Mg DM $ha^{-1}$) than that observed with a 7 kg $ha^{-1}$ rate.

Total N harvested (Table 3.3) was highest using the herbicide treatment ($P < 0.05$), and was positively correlated with legume DM harvested ($r = 0.94$), but not correlated with total DM harvested ($r = -0.06$). Mean legume CP concentration was 94 g $kg^{-1}$ DM and was not affected by method of establishment. Aeschynomene forage from the 7 kg $ha^{-1}$ seeding rate treatment was higher in CP than that from the 14 kg $ha^{-1}$ rate ($P = 0.02$), but the 6 g $kg^{-1}$ DM (97 vs. 91 g CP $kg^{-1}$ DM) difference may be of little biological significance. Limpograss CP concentration was very low (Table 3.3), and it was affected by establishment method ($P < 0.01$). There was a strong positive correlation between grass CP concentration and percentage legume in total DM harvested ($r = 0.83$).

Table 3.2. Dry matter harvested and botanical composition of aeschynomene-limpograss associations as affected by aeschynomene establishment method (1983).

| Method | 1983 DM harvested: Total | Grass | Legume | Legume in total DM |
|---|---|---|---|---|
| | Mg ha$^{-1}$ | | | % |
| Seeder | 12.9 a† | 9.2 a | 3.7 c | 28 c |
| Broadcast | 12.7 a | 9.0 a | 3.7 c | 30 c |
| Disk | 11.3 b | 4.8 b | 6.5 b | 58 b |
| Herbicide | 9.8 c | 1.8 c | 8.0 a | 82 a |
| SE‡ | 0.36 | 0.44 | 0.36 | 2.9 |

†Means within columns followed by the same letter are not significantly different (Duncan's multiple range test, P = 0.01).
‡Standard error of a treatment mean.

Table 3.3. The effect of aeschynomene establishment method on N harvested in total and legume herbage from aeschynomene-limpograss associations and on limpograss crude protein (CP) concentration (1983).

| Method | Nitrogen harvested: Total | Nitrogen harvested: Legume | Grass CP |
|---|---|---|---|
| | kg ha$^{-1}$ | | g kg$^{-1}$ DM |
| Seeder | 87 c† | 57 c | 20 c |
| Broadcast | 84 c | 55 c | 20 c |
| Disk | 115 b | 96 b | 25 b |
| Herbicide | 135 a | 125 a | 37 a |
| SE‡ | 5.3 | 5.8 | 1.2 |

†Means within columns followed by the same letter are not significantly different (Duncan's multiple range test, P = 0.05).
‡Standard error of a treatment mean.

Germination and Seedling Development: 1984

In 1984, seeding at four different dates provided a wide range of soil and climatic conditions for evaluation of aeschynomene establishment (Table 3.4). Rainfall totaled 60 mm in the first 4 days after the 1 April seeding, but nighttime temperatures were as low as 4°C. Little rain fell following the 20 April seeding, but soil moisture levels remained adequate for germination and emergence if the seed had been incorporated into the soil by disking and cultipacking. By 10 May, soil moisture was severely depleted and few seeds germinated before rains on 23 May. Both temperature and rainfall were favorable for the 20 June seeding, and seedlings emerged within 2 days of planting. Limpograss was 4, 6, 10, and 25 cm tall on 1 April, 20 April, 10 May, and 20 June, respectively, so responses to seeding date include the effects of differing levels of grass competition.

Legume seedling number was affected by date, rate, and method main effects at all stand count dates ($P \leqslant 0.01$), and interactions were numerous. Ten days after seeding there were more aeschynomene seedlings in disked plots than in the broadcast plots ($P \leqslant 0.05$) for the April seedings only (Table A-2). At 20 and 30 days after seeding, the disk treatment was superior over all dates ($P < 0.01$). There was a date x rate interaction for all three stand counts ($P < 0.01$). The 14 kg $ha^{-1}$ rate generally had more seedlings than did the 7 kg $ha^{-1}$ rate, but differences were most pronounced for the 20- and 30-day counts of the last two seeding dates (Table A-3). The number of seedlings that emerged tended to increase as date of seeding was

Table 3.4. Soil and climatic conditions for the first 20 days following seeding of aeschynomene in limpograss sods (1984).

| | | Days 1-10 | | | | Days 11-20 | | | |
|---|---|---|---|---|---|---|---|---|---|
| Seeding date | Initial SWC† | Mean SWC | Rain-fall | Mean ST | Mean AT | Mean SWC | Rain-fall | Mean ST | Mean AT |
| | g kg$^{-1}$ | g kg$^{-1}$ | mm | °C | °C | g kg$^{-1}$ | mm | °C | °C |
| 1 Apr. | 210 | 220 | 70 | 23 | 23–7 | 200 | 5 | 24 | 23–7 |
| 20 Apr. | 170 | 150 | 7 | 29 | 28–8 | 120 | 11 | 31 | 30–13 |
| 10 May | 90 | 90 | 0 | 31 | 29–10 | 180 | 111 | 30 | 30–15 |
| 20 June | 180 | 170 | 93 | 30 | 33–15 | 140 | 68 | 33 | 33–16 |

†SWC = soil water content (0 to 2 cm), ST = soil temperature (2-cm depth), AT = daily high and low air temperatures.

delayed, and emergence was greatest for the 20 June seeding ($P < 0.05$).

Dry Matter and N Harvested: 1984

Total and legume DM harvested were less in 1984 than in 1983 due to the two-cut system and to dry weather during August and September. There were date x method interactions for both legume and total DM responses in 1984 ($P < 0.01$). Aeschynomene DM harvested was greater with the disk treatment than with the broadcast treatment for seeding dates 1 April, 20 April, and 20 June (Table 3.5). Total DM harvested was greater using the disk treatment for the two April seedings, but for the 10 May and 20 June seedings there were no differences due to establishment method. Legume DM harvested was greatest for the 20 April seeding when comparing date means within the disk method ($P < 0.05$). There was a similar trend for the broadcast treatment, but seeding date responses were not significantly different. With the disk treatment, total DM harvested was greatest for the April seedings ($P < 0.05$), but with the broadcast treatment there was no date effect. Legume DM harvested in 1984 was 0.5 Mg $ha^{-1}$ greater with the 14 as opposed to the 7 kg $ha^{-1}$ seeding rate ($P < 0.01$, Table 3.6). Total DM harvested followed a similar pattern ($P < 0.01$), but limpograss DM harvested was not affected by seeding rate ($P = 0.26$).

Total N harvested in 1984 was correlated with both aeschynomene ($r = 0.98$) and total DM harvested ($r = 0.84$). There was a method x date interaction for total N harvested ($P < 0.01$), and specific responses closely paralleled those of total DM harvested. Increasing

Table 3.5. Legume seeding date x establishment method interaction means for total and legume dry matter (DM) harvested in aeschynomene-limpograss associations (1984).

| Seeding date | Total DM harvested | | Legume DM harvested | |
|---|---|---|---|---|
| | Method | | Method | |
| | Disk | Broadcast | Disk | Broadcast |
| | Mg ha$^{-1}$ | | | |
| 1 Apr. | 6.8 a† | 4.8 b | 1.9 a | 0.5 b |
| 20 Apr. | 7.5 a | 5.1 b | 3.9 a | 1.0 b |
| 10 May | 5.3 a | 4.9 a | 1.1 a | 0.6 a |
| 20 June | 5.6 a | 5.3 a | 1.1 a | 0.3 b |
| SE‡ | 0.17 | | 0.11 | |

†Establishment method means within dates followed by the same letter are not significantly different (LSD, P = 0.05).
‡Standard error of an establishment method mean.

Table 3.6. Dry matter and N-harvested responses to legume seeding rate in aeschynomene-limpograss associations (1984).

| Seeding rate | DM harvested | | | Nitrogen harvested | | | Grass CP |
|---|---|---|---|---|---|---|---|
| | Total | Grass | Legume | Total | Grass | Legume | |
| kg ha$^{-1}$ | Mg ha$^{-1}$ | | | kg ha$^{-1}$ | | | g kg$^{-1}$ DM |
| 7 | 5.3 | 4.2 | 1.1 | 40 | 16 | 24 | 24 |
| 14 | 6.1 | 4.5 | 1.6 | 54 | 19 | 35 | 26 |
| F test† | ** | NS | ** | ** | * | * | * |
| SE‡ | 0.17 | 0.14 | 0.11 | 3.3 | 0.7 | 3.1 | 0.5 |

†NS = not significant, * and ** indicate probability levels of $P \leq 0.05$ and $P \leq 0.01$.

‡Standard error of a treatment mean.

aeschynomene seeding rate from 7 to 14 kg $ha^{-1}$ increased total ($P < 0.01$), legume ($P = 0.02$), and grass N harvested ($P = 0.02$, Table 3.6). Limpograss CP concentration was not affected by seeding rate at the 12 July harvest ($P = 0.26$), but by 3 October grass CP was 2 g $kg^{-1}$ DM higher in plots where the legume was seeded at 14 kg $ha^{-1}$ ($P = 0.05$). As in 1983, grass CP concentration was positively correlated with percentage legume in total forage DM ($r = 0.72$). Grass from disked plots was higher in CP concentration than grass from the broadcast plots ($P = 0.03$). Legume CP concentration averaged 140 g $kg^{-1}$ DM using the two-cut system in 1984. This was nearly 50 g $kg^{-1}$ DM greater than in the very mature, woody plants harvested in September 1983, and more closely represents concentrations observed under grazing (Chapter V).

## Discussion

### Germination and Seedling Development

Oversowing of legumes into grass pastures, either by sod-seeding or surface broadcasting, has the potential to improve forage quality while minimizing pasture renovation costs (Cook, 1980). In the current study, favorable rainfall and temperature conditions after seeding on 3 June 1983 resulted in no differences in legume establishment between four oversowing methods. These results are similar to those reported by Gomes (1978) for an aeschynomene-Bigalta association. By contrast, seeding occurred at four dates in 1984, and under the influence of a wide range of climatic and soil conditions, incorporating seeds into the soil (disk method) was generally superior to broadcasting seeds on the soil surface.

Some factors that may have limited germination and seedling development at the respective 1984 seeding dates can be proposed. The combination of low nighttime temperatures and wet soils following the 1 April seeding may have been detrimental. No reports of cold temperature effects on aeschynomene establishment have been found in the literature. Minimal rainfall following seeding on 20 April rendered the broadcast treatment ineffective, and emphasized the importance of incorporating the seed into a moist soil if rainfall is sporadic or unpredictable. Almost no germination occurred after the 10 May seeding until rain fell nearly 2 weeks later. Some seeds that were broadcast on the soil surface may have imbibed water from dew on litter and grass and initiated germination, only to desiccate and die when no rain fell. Conditions were excellent on 20 June and aeschynomene seedlings emerged quickly. However, limpograss was 25 cm tall by this date, and grass competition limited legume establishment. Similar responses have been reported for Townsville stylo (*Stylosanthes humilis* H.B.K.) over-seeded in tall perennial grass pastures (Gillard, 1977).

## Dry Matter and N Harvested

Results from 1983 indicate that aeschynomene production was strongly related to the degree of limpograss canopy reduction. The grass was very slow to initiate new growth after treatment with paraquat, thus allowing the legume 4 to 5 weeks of growth without significant above-ground grass competition. Disking opened up the canopy but did not curb grass competition to the extent that the herbicide treatment did. The sod seeder had little effect on grass competition, and broadcast seeding had none. Legume DM responses were comparable to those reported by Kalmbacher et al. (1978). They observed that herbicidal suppression of bahiagrass enhanced establishment and productivity of three summer-annual legumes, but high rates of some compounds reduced bahiagrass stands. In further work with an aeschynomene-bahiagrass association, Kalmbacher and Martin (1983) found that a paraquat plus burn treatment prior to seeding, or a grazing treatment after seeding the legume, controlled grass competition and allowed the legume to become established. Total DM and grass DM harvested were inversely related to the amount of sod disturbance in the current study, and similar results have been reported (Kalmbacher and Martin, 1983). Increasing legume seeding rate tended to increase DM harvested in 1983, but it had no effect on total or limpograss DM harvested.

Nitrogen harvested in 1983 was closely related to legume DM harvested but was not related to total DM produced. The lack of relationship between total DM and total N harvested is unusual with forages in general, but it illustrates the effect of very low limpograss CP concentrations. Grass CP concentration was highly correlated with percentage legume in sward DM, but these results must be interpreted with caution. Highest percentage legume occurred in paraquat-treated swards where the grass was forced to regenerate new shoots. The harvested portion of the grass forage was mainly this younger growth which likely would be higher in CP. Also, disking may have encouraged mineralization of soil N, making more available to the N-deficient grass. Some N may have been made available to the grass by the legume, but other factors probably were involved.

Aeschynomene typically is seeded after the onset of summer convectional rains in Florida (Hodges et al., 1982), but this practice severely limits the productive period of the legume. The 1984 experiment provides evidence that earlier seeding may be possible in some years. Total DM harvested was maximized with April seeding dates, and legume contribution was greatest when seeded on 20 April. Earlier seedings were more successful in 1984 because soil moisture levels were higher in April than for the May seeding, and because grass competition was minimal in April compared to the level at the June seeding. Clipping the grass to a 5-cm stubble before each seeding date may have been a better way to isolate the effects of soil and climatic conditions.

The disk and broadcast methods were selected for additional evaluation in 1984 because they require less specialized equipment or are less costly than the sod seeder or herbicide methods. As a result they may be more attractive options for pasture improvement in Florida. As in 1983, the disk treatment was superior to the broadcast treatment in 1984. Differences due to method were more closely related to effects on establishment in 1984 than they were in 1983, when later-season effects of grass competition may have been more critical. Apparent benefits of the disk-cultipack treatment include better soil-seed contact, some control of grass competition, and more light penetration to the base of the canopy. Broadcasting dehulled aeschynomene seed on the soil surface has been used successfully (Chapter IV), but adequate rainfall after seeding and control of grass competition by grazing were necessary.

In contrast to 1983, legume seeding rate was important in 1984, probably due to less favorable conditions at establishment. The higher seeding rate increased total and legume DM harvested, and total, limpograss, and aeschynomene N harvested. These results are in contrast with work done on prepared seedbeds in Australia. Middleton (1970) reported that increasing the rate of sowing of one component of a grass-legume mixture raised its contribution to DM and N harvested, but decreased that of its associated species. In Pennsylvania, higher legume seeding rates increased legume contribution, grass DM harvested, and grass CP concentration (Sollenberger et al., 1984).

From this and other experiments, several major factors affecting aeschynomene establishment are indicated. These include soil moisture at seeding, rainfall in the first 10 days after seeding (Kalmbacher and Martin, 1983), soil temperature, light penetration to the base of the canopy (Kalmbacher and Martin, 1983), and control of grass competition until the legume seedling is 3 to 5 cm tall (Hodges et al., 1982; Kalmbacher and Martin, 1983; Sollenberger et al., 1985). High legume seeding rates appear to be beneficial, particularly when establishment conditions are unfavorable. A large number of methods can be used to establish aeschynomene, but there is less risk involved when the seed is incorporated into a warm, moist soil, and when the method utilized offers extended control of grass competition.

CHAPTER IV
EFFECTS OF GRAZING MANAGEMENT ON PRODUCTIVITY AND BOTANICAL COMPOSITION OF AN *Aeschynomene americana*-*Hemarthria altissima* ASSOCIATION

## Introduction

Limpograss [*Hemarthria altissima* (Poir.) Stapf et C.E. Hubb.] is a highly productive tropical grass with potential for use in the lower Southeast (Quesenberry et al., 1978). Digestibility (IVOMD) and organic matter intake of limpograss were generally superior to that of bahiagrass (*Paspalum notatum* Flugge), the predominant pasture species in Florida (Carvalho, 1976; Moore et al., 1981), but N concentration in limpograss forage may be very low (Euclides, 1985).

Generally, the most economical alternative for overcoming a protein deficiency in pastures is to include a legume (Minson, 1980). Aeschynomene (*Aeschynomene americana* L.) is the most widely adapted warm-season legume available for grazing in Florida (Hodges et al., 1982). Kalmbacher et al. (1978) reported that herbicidal suppression of bahiagrass sods facilitated aeschynomene establishment and increased total dry matter (DM) harvested and crude protein concentration of the association. Excellent aeschynomene stands have also been obtained by grazing bahiagrass to a 3- to 5-cm stubble, drilling legume seed into the sod, and occasionally grazing the area until aeschynomene seedlings were 2.5 cm tall (Kalmbacher and Martin, 1983).

Mislevy et al. (1981) reported highest seasonal DM harvests of aeschynomene if the legume was cut initially at a height of 30 cm, with the regrowth cut at 90 cm. Lowest production occurred when the legume was clipped at 30 cm throughout the season. Under grazing, aeschynomene was most productive if defoliated first at 28-, instead of 45- or 54-cm heights (Gildersleeve, 1982). Early grazing was credited with opening up the canopy for better light penetration and stimulating axillary bud development and secondary branching.

Establishment of aeschynomene into limpograss sods and subsequent management of the association have not been evaluated under grazing conditions. Since both species are well adapted to the large expanses of poorly drained flatwoods soils in Florida, this type of information is needed. The objectives of this research were 1) to evaluate the effects of spring grazing management of limpograss on aeschynomene establishment and subsequent productivity, and 2) to compare the effects of summer grazing management of the association on legume and total DM accumulated and sward botanical composition.

## Materials and Methods

An experiment was conducted in 1983 and 1984 at the University of Florida's Forage Evaluation Field Laboratory, located northeast of Gainesville, Florida (lat 29° 60' N). The research site was a 2-ha 'Floralta' limpograss pasture that had been established in 1981. Soils were of the Pomona series (sandy, siliceous, hyperthermic Ultic Haplaquod). Prior to initiating the experiment in 1983, soil pH at the site was 5.6, and Mehlich I extractable P and K levels were 4 and

18 mg $kg^{-1}$, respectively. In 1984, soil pH was 5.6, and P and K levels were 6 and 34 mg $kg^{-1}$. Guided by soil test results, P and K were broadcast applied at rates of 44 and 166 kg $ha^{-1}$ in 1983, and 70 and 133 kg $ha^{-1}$ in 1984. Twenty kilograms $ha^{-1}$ of a micronutrient mixture (F-503 Oxide) were included with the P and K in both years. Lime was applied at a rate of 2.2 Mg $ha^{-1}$ in April 1984 because soil pH was nearly 5.0 in some areas of the pasture.

Experimental variables included 1) limpograss stubble height when aeschynomene was overseeded (SH), 2) legume seedling growth stage when early-season grazing was discontinued (LSGS), and 3) legume height when summer grazing was initiated. Early-season limpograss regrowth was grazed to a 7.5- or 15-cm stubble. At the onset of summer rains (7 June 1983 and 20 June 1984) dehulled, scarified, and inoculated aeschynomene seed was broadcast at a rate of 20 kg $ha^{-1}$ using a cyclone seeder. Following overseeding, cattle were rotated among the pastures to maintain the prescribed grass stubble heights. Grazing was discontinued 1) when legume cotyledons were exserted, 2) when two-true leaves were present, or 3) 2 weeks after the two-leaf stage. Pastures were not grazed subsequently until the legume reached heights of 20, 40, or 80 cm in 1983 and 20, 40, or 60 cm in 1984. Following initiation of grazing at the respective heights, all pastures were grazed rotationally with a rest period of 5 weeks. Defoliation was by mob grazing to an 8- to 12-cm stubble. Exceptions were pastures where grazing was not initiated until the legume was 60 to 80 cm tall. The yearling and 2-year-old steers (Bos spp.) would not graze the mature herbage to a low stubble, so a more subjective visual appraisal of the pasture was made to determine when grazing should end.

The complete factorial set of treatments (2 x 3 x 3) was arranged in a split-split plot design in 1983 and a split-plot design in 1984. Grass SH was the whole-plot treatment in both years, and LSGS was the subplot treatment in 1983. The design was changed in 1984 to provide a stronger test for LSGS differences, despite the original design being more convenient for animal management. Legume seedling growth stage means were compared using the single degree of freedom contrasts, cotyledon vs. two-leaf stage, and cotyledon plus two-leaf stage vs. 2 weeks after the two-leaf stage. Initiation height effects were evaluated using orthogonal polynomials to determine the nature of response curves. Percentage legume in total herbage accumulated and in total herbage consumed was transformed (square root) prior to analysis of variance (Steel and Torrie, 1960). All treatments were replicated twice in each year, and pasture size was 500 $m^2$.

Stand counts were taken at 10, 20- by 20-cm locations in each pasture when legume seedlings reached the cotyledon stage (3 days after seeding), the two-leaf stage (10 days after seeding), and the two leaf plus 2-week stage (24 days after seeding). In 1984 the cotyledon count was delayed until 5 days after seeding due to logistical constraints. The same areas were counted at each growth stage, so that population trends could be monitored.

In 1983, pastures defoliated initially when the legume was 20, 40, and 80 cm were grazed four, three, and two times (cycles), respectively. In 1984, both 20- and 40-cm treatments were grazed three times, and the 60-cm treatment was grazed twice. Grazing seasons for the legume-grass association extended from 11 July through 4 Nov. 1983 and 23 July through 2 Nov. 1984.

All pastures were sampled before and after each grazing period. Response variables measured include herbage mass, percentage aeschynomene, percentage limpograss, and percentage weeds. A double sampling technique was used that combined visual estimates made by a single observer, and actual values determined by cutting forage to ground level and hand separating the fresh herbage (Stockdale, 1984).

Five double sampling sites were selected in each pasture before and after grazing. The 0.5-$m^2$ sites were not chosen at random, but were chosen to represent the range of the response variables present in a given pasture. Visual estimates of the four response variables were recorded at each site. The forage was then clipped, hand separated into aeschynomene, limpograss, and weed fractions, dried at 60°C for 48 hours, and weighed. Actual values were calculated and regression equations fit for actual values vs. visual estimates (regression was through the origin). The slope of the regression line was used to correct the mean of 30 visual estimates that were taken at randomly selected locations in each pasture. This corrected mean is the reported value for each response variable.

Generally, data from all pregraze or all postgraze sites of a given week (30 to 40 double samples) were combined to form a regression equation. Occasionally, higher $r^2$ values and lower standard errors of the estimate were obtained if the pastures grazed in 1 week were divided into two or more groups and separate equations fit. Similarly, there were times when single equations were used for 2 or more weeks of sampling.

As recommended by Hodgson (1979), terms such as herbage yield and herbage production are avoided in this report. Suggested terms that are used include 1) herbage mass, the instantaneous measure of total weight of herbage per unit area of ground, 2) herbage accumulation, the change in herbage mass between successive measurements and summed over time where appropriate, 3) herbage consumed, the mass of herbage per unit area removed by grazing animals at a single grazing or series of grazings, and 4) efficiency of grazing, the herbage consumed expressed as a proportion of herbage accumulation (Hodgson, 1979). Botanical composition data, unless otherwise specified, are expressed as a percentage of herbage DM accumulated. When botanical composition is expressed on a yearly basis, it was calculated as the summation of component DM accumulated (over grazing cycles) x 100 and divided by the summation of total DM accumulated. As grazing periods were generally 48 hours, plant growth during grazing was not accounted for ('t Mannetje, 1978).

## Results

### Aeschynomene Seedling Counts

Changes in legume seedling populations throughout the establishment period were used to draw conclusions about the effects of SH and LSGS on aeschynomene seedling survival. There was no effect of SH on seedling emergence ($P = 0.13$ in 1983, and $P = 0.80$ in 1984), or seedling survival ($P \geq 0.55$) in either year. In contrast, LSGS did affect seedling survival in both years (Table 4.1). In general, continuing to graze pastures beyond the cotyledon stage resulted in greater losses of aeschynomene seedlings than that observed in pastures where grazing ended at cotyledon exsertion.

Total DM Accumulation

Measurement of DM accumulation started when summer grazing of the grass-legume associations was initiated. As a result, treatments which minimized grazing during legume establishment tended to have higher seasonal accumulation of herbage DM. The 15-cm SH treatment accumulated 9.59 Mg DM $ha^{-1}$ in 1983 compared to 8.15 Mg $ha^{-1}$ for the 7.5-cm treatment ($P = 0.02$). In 1984, the same treatments accumulated 8.10 and 6.62 Mg of herbage $ha^{-1}$,respectively ($P = 0.16$). If grazing ended early during the legume establishment period, i.e., at the cotyledon or two-leaf stage, DM accumulation was greater than that observed if grazing continued for 2 weeks after the two-leaf stage ($P = 0.05$ in 1983, and $P < 0.01$ in 1984). Total DM accumulation was 9.88, 8.95, and 7.79 Mg $ha^{-1}$ for the cotyledon, two-leaf, and two leaf plus 2-weeks treatments in 1983, and 7.99, 7.47, and 6.62 Mg $ha^{-1}$ in 1984. There was no SH x LSGS interaction in either year ($P \geqslant 0.62$).

Legume height at initiation of summer grazing also influenced annual DM accumulation ($P = 0.01$ in 1983 and $P = 0.03$ in 1984, Table 4.2). The effect of height on total DM was quite different in the first as compared to the second grazing cycle (Table 4.2). In general, delaying the date of first grazing increased cycle 1 DM

Table 4.1. Changes in aeschynomene seedling population as affected by legume seedling growth stage (LSGS) when early-season grazing ended.

| LSGS | 1983 Period† | | | 1984 Period | | |
|---|---|---|---|---|---|---|
| | C-2L | 2L-2L2 | C-2L2 | C-2L | 2L-2L2 | C-2L2 |
| | Change in seedling number $m^{-2}$ | | | | | |
| Cotyledon | 68‡ | -31 | 37 | 5 | 3 | 8 |
| Two leaf | 50G | -49 | 1g | -38G | 6 | -32g |
| Two leaf plus 2 weeks | 48G | -80G | -32G | -23G | -23G | -46G |
| SE§ | 11 | 13 | 10 | 8 | 10 | 10 |
| F test | NS | NS | * | ** | NS | ** |
| Contrasts¶ | - | - | S,* | **,NS | - | **,** |

†Period C-2L is the interval between the cotyledon and two-leaf stages. Period 2L-2L2 is the interval between the two-leaf and two leaf plus 2-weeks stages, and period C-2L2 is the combined interval between the cotyledon and two leaf plus 2-weeks stages.

‡Positive and negative numbers reflect increases or decreases in legume seedling population during a given period. Mean seedling number at cotyledon stage was 156 and 217 $m^{-2}$ in 1983 and 1984. Following a number, the letter G indicates treatments that were grazed throughout a period, while g indicates those that were grazed for part of a period. No letter following the number means no grazing occurred during the period.

§Standard error of a treatment mean.

NS = not significant, S, *, and ** indicate significance at $P \leqslant 0.10$, $P \leqslant 0.05$, and $P \leqslant 0.01$, respectively.

¶Probability levels are given for single degree of freedom contrasts of cotyledon vs. two-leaf stage, and cotyledon plus two-leaf stage vs. 2 weeks after the two-leaf stage.

accumulation, decreased that observed in cycle 2, but increased annual DM accumulation.

Component DM Accumulation and Sward Canopy Botanical Composition

Limpograss SH did not affect legume DM accumulation in either year ($P = 0.82$ in 1983, and $P = 0.35$ in 1984). Mean legume DM accumulations in 1983 and 1984 were 1.35 and 1.30 Mg $ha^{-1}$ for the 7.5-cm SH, compared to 1.18 and 1.04 Mg $ha^{-1}$ for the 15-cm treatment. The proportion of total forage accumulated that was legume DM was 15.5 and 20.7% for the 7.5-cm height, while that of the 15-cm treatment was 12.7 and 13.2% in 1983 ($P = 0.74$) and 1984 ($P = 0.17$), respectively.

In both years, percentage aeschynomene in total DM accumulated increased with longer periods of grazing during legume establishment (Table 4.3). Legume DM accumulation followed a similar pattern in 1984 ($P \leqslant 0.01$). In 1983 there was only a trend in legume DM accumulation favoring continued grazing beyond the cotyledon stage ($P = 0.30$).

Aeschynomene height when plants were first defoliated affected annual accumulation of legume DM (Table 4.4). The response of legume DM accumulation to initiation height was very different in cycle 1 than it was in cycle 2 (Table 4.4). This response was consistent in both years, as plants that were first grazed at 60 or 80 cm produced almost all of their seasonal total of aeschynomene DM in the first grazing cycle, while those plants grazed initially at 20 or 40 cm provided a more uniform distribution of legume DM throughout the season.

Table 4.2. The effect of legume height at initiation of summer grazing (HI) on cycle 1 (C1), cycle 2 (C2), and annual (AN) total dry matter accumulation of aeschynomene-limpograss associations.

| HI | 1983 | | | 1984 | | |
|---|---|---|---|---|---|---|
| | C1 | C2 | AN | C1 | C2 | AN |
| — cm — | Mg $ha^{-1}$ | | | | | |
| 20 | 3.24 | 3.77 | 8.57 | 4.39 | 1.48 | 6.85 |
| 40 | 5.03 | 2.49 | 8.28 | 5.63 | 1.33 | 7.73 |
| 80,60† | 9.60 | 0.17 | 9.77 | 7.05 | 0.44 | 7.49 |
| SE‡ | 0.31 | 0.21 | 0.31 | 0.14 | 0.15 | 0.14 |
| F test§ | L** | L** | L**,Q | L** | L**,Q | L*,Q* |

†Aeschynomene HI was 80 cm in 1983 and 60 cm in 1984.
‡Standard error of a treatment mean.
§Linear (L) or quadratic (Q) effects with probability of $P \leq 0.01$ (**), $P \leq 0.05$ (*), or $P \leq 0.10$ (letter listed, but not followed by a symbol).

Table 4.3. The effect of legume seedling growth stage (LSGS) when early-season grazing ended on aeschynomene dry matter (DM) accumulation and percentage legume in aeschynomene-limpograss associations.

| LSGS | Legume DM accumulation 1983 | Legume DM accumulation 1984 | Percentage legume in sward DM 1983 | Percentage legume in sward DM 1984 |
|---|---|---|---|---|
| | —— $Mg\ ha^{-1}$ —— | | | |
| Cotyledon | 0.83 | 0.96 | 8.6 | 12.1 |
| Two leaf | 1.54 | 1.10 | 16.4 | 15.6 |
| Two leaf plus 2 weeks | 1.43 | 1.46 | 17.4 | 23.2 |
| SE† | 0.30 | 0.09 | -- | -- |
| F test | NS | ** | S | ** |
| Contrasts‡ | -- | NS,** | S,NS | S,** |

†Standard error of a treatment mean. Standard errors are not presented for percentage data, as analysis of variance was performed on transformed values (square root), and the means presented have been transformed back to the original scale.

NS = not significant, S and ** indicate probability levels of $P \leqslant 0.10$ and $P \leqslant 0.01$.

‡Single degree of freedom contrasts of cotyledon vs. two-leaf stage, and cotyledon plus two-leaf stage vs. 2 weeks after the two-leaf stage.

Table 4.4. The effect of aeschynomene height at initiation of summer grazing (HI) on cycle 1 (C1), cycle 2 (C2), and annual (AN) aeschynomene (A) and limpograss (LG) dry matter accumulation in aeschynomene-limpograss associations.

| | 1983 | | | | | | 1984 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | C1 | | C2 | | AN | | C1 | | C2 | | AN | |
| HI | A | LG | A | LG | A | LG | A | LG | A | LG | A | LG |
| — cm — | Mg ha$^{-1}$ | | | | | | | | | | | |
| 20 | 0.08 | 2.28 | 0.47 | 2.41 | 0.99 | 5.30 | 0.20 | 2.68 | 0.50 | 0.62 | 1.04 | 3.84 |
| 40 | 0.30 | 3.64 | 0.23 | 1.46 | 0.74 | 5.31 | 0.53 | 3.32 | 0.31 | 0.99 | 1.05 | 4.71 |
| 80,60† | 2.03 | 5.64 | 0.04 | 0.18 | 2.07 | 5.82 | 1.38 | 3.84 | 0.04 | 0.60 | 1.42 | 4.44 |
| SE‡ | 0.17 | 0.34 | 0.07 | 0.21 | 0.14 | 0.34 | 0.06 | 0.23 | 0.04 | 0.13 | 0.09 | 0.31 |
| F test§ | L**,Q | L** | L** | L** | L**,Q** | NS | L**,Q** | L** | L** | Q* | L** | NS |

†Aeschynomene HI was 80 cm in 1983 and 60 cm in 1984.

‡Standard error of a treatment mean.

§Linear (L) or quadratic (Q) effects with probability of $P \leq 0.01$ (**), $P \leq 0.05$ (*), or $P \leq 0.10$ (letter listed, but not followed by a symbol). NS = not significant.

In both years, cycle 1 limpograss DM accumulation increased linearly as initiation of grazing was delayed, but annual DM accumulation was not affected by initiation height ($P = 0.48$ in 1983, and $P = 0.16$ in 1984, Table 4.4). Grass DM accumulation for the 1983 season was not affected by LSGS ($P = 0.14$) or by SH ($P = 0.34$). In 1984, there was no response of limpograss DM accumulated to SH ($P = 0.33$), but LSGS effects were important ($P < 0.01$). Pastures grazed through the cotyledon, two-leaf, and two leaf plus 2-weeks stages accumulated 5.12, 4.44, and 3.43 Mg of grass DM $ha^{-1}$ (for the contrast cotyledon vs. two-leaf stage, $P = 0.14$, and for the contrast cotyledon plus two-leaf stage vs. 2 weeks after two-leaf stage, $P < 0.01$).

Annual totals for weed DM accumulation were not affected by SH ($P = 0.63$ in 1983, $P = 0.84$ in 1984), LSGS ($P = 0.72$ in 1983, and $P = 0.84$ in 1984), or initiation height ($P = 0.12$ in 1983, and $P = 0.47$ in 1984). Major weed species in the pastures included vaseygrass (*Paspalum urvillei* Steud.) and various sedges (*Cyperus* spp.).

## Herbage Consumed and Grazing Efficiency

Total DM consumed in 1983 was not affected by grazing management, but trends were evident. Animals consumed 6.62 Mg DM $ha^{-1}$ on 15-cm SH pastures compared to 5.36 Mg $ha^{-1}$ for the 7.5-cm treatment ($P = 0.16$). Dry matter consumed tended to be higher when establishment-period grazing ended early ($P = 0.11$), as totals were 6.79, 6.07, and 5.12 Mg $ha^{-1}$ for the cotyledon, two-leaf, and two leaf plus 2-weeks treatments. There was no response of total DM consumed to initiation height ($P = 0.26$). Trends were, however, quite different from those of DM accumulation (Table 4.2). Dry matter consumption for 20-, 40-, and 80-cm treatments was 6.36, 6.05, and 5.56 Mg $ha^{-1}$, respectively. Grazing efficiency decreased linearly ($P < 0.01$) as initiation height increased. Grazing efficiency means for 20-, 40-, and 80-cm initiation heights were 74, 66, and 61%, respectively.

In 1984, total DM consumed for 7.5- and 15-cm SH treatments was 4.51 and 3.95 Mg $ha^{-1}$, respectively ($P = 0.42$). Similar to the response observed in 1983, total DM consumed for cotyledon, two-leaf, and two leaf plus 2-weeks LSGS levels was 4.66, 4.18, and 3.85 Mg $ha^{-1}$, respectively (cotyledon > two-leaf stage, $P = 0.07$; cotyledon plus two-leaf stage > 2 weeks after two-leaf stage, $P = 0.02$). There were linear ($P < 0.01$) and quadratic ($P = 0.10$) effects of aeschynomene height at first grazing on total DM consumed in 1984. Treatment means for 20-, 40-, and 60-cm initiation heights were 4.14, 4.85, and 3.71 Mg of DM consumed $ha^{-1}$, respectively. Grazing efficiency responded to initiation height in 1984 (linear and quadratic effects, $P < 0.01$), and treatment means for 20-, 40-, and 60-cm heights were 61, 63, and 49%, respectively.

## Animal Selection

As well as evaluating the effects of grazing management on the association, it was also of interest to determine if animals were selecting for or against any of the botanical components. The botanical composition of total herbage accumulated (HA), total herbage mass (HM) at initiation of grazing (summed over all cycles), and total herbage consumed (HC), was calculated for both years, and the means over all grazing treatments were determined (Table 4.5). These data suggest selection for aeschynomene and against weeds, but without knowing the vertical distribution of component DM in the canopy, conclusions regarding animal selection could not be drawn.

As part of a concurrent experiment evaluating ingestive behavior of cattle (Moore et al., in press), 24 pastures were characterized in 1983 using a stratified clipping technique. For these pastures, forage from the bottom of the canopy (the bottom 10 cm for most pastures, the bottom 30 cm for pastures 60 cm tall or taller) was not included in calculating the botanical composition of the upper layers (UL). Using data from both experiments for these 24 pastures, regression analysis was used to evaluate the relationship of percentage of a component (e.g., aeschynomene) in UL vs. that in HM, percentage of the component in HC vs. that in HM, and percentage of the component in HC vs. that in UL (Table 4.6). It is apparent from these equations that the relationship between UL botanical composition and HM botanical composition was similar to the relationship between HC botanical composition and HM botanical composition. It is apparent that intercepts approach zero and slopes approach one for the regression of diet botanical composition (HC) vs. upper layers botanical composition (UL). This suggests that the botanical composition of the diet was very similar to that of the upper layers of the sward.

## Discussion

Excellent legume stands were obtained in both years, as adequate rainfall following seeding (> 3 cm within 48 hours) insured rapid

Table 4.5. The percentage of total herbage accumulated (HA), total herbage mass at initiation of grazing (HM), and total herbage consumed (HC) that was aeschynomene, limpograss, and weed dry matter.

| Botanical component | 1983 HA | 1983 HM | 1983 HC | 1984 HA | 1984 HM | 1984 HC |
|---|---|---|---|---|---|---|
| | % | | | | | |
| Legume | 14 | 10 | 18 | 17 | 12 | 27 |
| Grass | 60 | 61 | 61 | 56 | 55 | 58 |
| Weeds | 26 | 29 | 21 | 27 | 33 | 15 |

†Values presented are means over all treatments for the grazing seasons of 1983 and 1984.

Table 4.6. Regression equations relating the percentages of three botanical components (aeschynomene, limpograss, and weeds) in total herbage in the upper layers of the sward (UL), in total herbage mass present at the beginning of a grazing cycle (HM), and in total herbage consumed during the grazing period (HC).

| Dependent variable† | Intercept | b | Independent variable | $r^2$ |
|---|---|---|---|---|
| Aeschynomene | | | | |
| UL‡ | 3.26 | 1.52 | HM | 0.94 |
| HC | 2.74 | 1.48 | HM | 0.94 |
| HC | 0.43 | 0.93 | UL | 0.91 |
| Limpograss | | | | |
| UL | -23.78 | 1.28 | HM | 0.90 |
| HC | -24.33 | 1.28 | HM | 0.75 |
| HC | 3.25 | 0.94 | UL | 0.74 |
| Weeds | | | | |
| UL | -4.35 | 0.95 | HM | 0.90 |
| HC | -5.00 | 1.07 | HM | 0.58 |
| HC | 0.81 | 1.07 | UL | 0.57 |

†Data for the equations were from 24 pastures and were means of five sites per pasture (corrected for actual pasture means that had been determined by double sampling).

‡Upper layers include herbage from 10 cm to the top of canopies less than 60 cm tall, and herbage from 30 cm to the top for canopies 60 cm tall or taller.

seedling emergence and prevented loss of seedlings due to desiccation. Grass SH did not affect aeschynomene germination, emergence, or seedling survival during the 24 days following seeding. Kalmbacher and Martin (1983) reported that numbers of aeschynomene seedlings emerging and surviving for 30 days were not different in ungrazed bahiagrass (20 to 30 cm tall) and in sods that were grazed to a 5-cm stubble until seedlings were 2.5 cm tall. Data from these experiments suggest that aeschynomene germination and early seedling survival is not significantly affected by moderate levels of grass competition. Long-term survival and subsequent productivity may suffer, however, as evidenced by the SH and LSGS trends described below.

Limpograss SH did not significantly influence legume productivity in either year, but there was a consistent trend over both years favoring the 7.5-cm SH. Studies have shown that tall grass limited the productivity of Stylosanthes humilis H.B.K. overseeded in native pastures (Gillard, 1977). Aeschynomene was more productive if seeded into a grazed bahiagrass sod than if seeded into bahiagrass that was 20 to 30 cm tall (Kalmbacher and Martin, 1983). Kalmbacher and Martin (1983) hypothesized that seedling development in a low-light environment is slower, increasing the length of time that plants are susceptible to disease and to insect or snail feeding. Decreased seedling root growth has also been associated with low-light environments (Groya and Sheaffer, 1981), making plants less able to tolerate drought or to compete effectively for nutrients. Thus, it appears that although aeschynomene seedlings survive for some time under taller grass, they are weakened by grass competition and eventually lost from the stand in greater numbers than seedlings in closely grazed grass sods. It is also likely that more extreme levels of grass competition lead to earlier legume seedling loss, as was the case for S. humilis in Australia (Gillard, 1977). Although data from the current research are not conclusive, grazing limpograss to an SH of approximately 7.5 cm may be advantageous, as even small improvements in legume performance could be important in N-deficient grass swards.

Data from both years indicate that LSGS was an important factor affecting legume seedling survival, legume DM accumulation, and percentage legume in pasture DM. Continued grazing after legume cotyledon exsertion decreased legume stands, suggesting that postemergence grazing should be strictly limited to only the amount required for control of grass competition. Stocking of the 500 $m^2$ pastures was approximately 2 animal days (yearling steers) $week^{-1}$ of establishment period grazing. It was noted that extending the period of grazing decreased the number of legume seedlings but increased subsequent legume DM accumulation. Apparently, the beneficial effect of long-term control of grass competition was greater than the short-term effect of reduced aeschynomene stands.

Similar responses of aeschynomene DM accumulation to prolonged establishment-period grazing have been reported (Hodges et al., 1982; Kalmbacher and Martin, 1983). Results of the current study suggest an advantage in maintaining closely grazed sods until aeschynomene seedlings are approximately 5 cm tall. In 1983, grazing through the two-leaf stage was adequate to maximize legume performance, but in 1984 highest aeschynomene DM accumulation occurred when grazing continued for an additional 2 weeks. This may have been related to the experimental area being burned prior to the 1983 season but not prior to 1984. Grass regrowth after burning was vigorous in 1983, but the canopy was more open at seeding than it was in 1984. With a less dense grass sod in 1983, extending the period of early grazing past the two-leaf stage may not have been as critical as it was in 1984.

Legume DM accumulation, legume DM consumed, and percentage legume in sward DM were maximized by initiating grazing when aeschynomene was 60 or 80 cm tall. The taller initiation height treatments accumulated more than 95% of their seasonal total of legume DM in cycle 1. This is in contrast to the 20-cm treatment that accumulated 56% of its 1983 total in cycles 1 and 2, and 44% in cycles 3 and 4. Grazing aeschynomene when it was 60 to 80 cm tall resulted in extensive trampling damage and stand loss. Those plants which survived had limited capability for regrowth, probably due to shading and death of lower axillary bud sites and to selective, and almost complete, removal of leaf tissue by animals. It should be stressed that these pastures were heavily grazed, and this undoubtedly compounded the problem of survival for tall, stemmy legume plants. Fisher (1973) reported that S. humilis withstood repeated defoliation to a 5-cm stubble if cutting started early in the season, but delaying cutting for 1 month resulted in 82% stand loss. Poor regrowth of tall aeschynomene after clipping or grazing has frequently been cited (Albrecht and Boote, in press; Gildersleeve, 1982; Mislevy et al., 1981; Tang and Ruelke, 1976), and these authors have suggested that shading and death of axillary buds on the lower portion of the stem is a major factor in this response. Gildersleeve (1982) observed that plants grazed initially at 28 cm were more productive, more persistent, and had more vigorous regrowth throughout the season than did plants that were first grazed at 45 or 54 cm. The author suggested that early grazing removed apical dominance, improved light penetration to the base of the canopy, and stimulated axillary bud development and secondary branching.

In the current study, measurement of total DM accumulation was limited to the summer grazing period. This provided an advantage to pastures that were grazed to the 15-cm SH, or that were grazed just through the cotyledon or two-leaf stages during establishment. If grass forage consumed during establishment was accounted for in total DM, differences due to SH and LSGS would likely be small or possibly not significant.

Aeschynomene height at initiation of summer grazing had a marked effect on total DM accumulation. In both years, cycle 1 DM accumulation increased linearly as initiation of summer grazing was delayed, but cycle 2 DM accumulation was lowest for the taller initiation height treatments. Several factors were likely responsible for lower productivity of the 80- and 60-cm treatments in the second cycle. First, during the initial grazing period large amounts of very mature forage were trampled, and stems, particularly of the legume, were broken and plants killed. Dead plant matter decayed during the 5-week rest period, partially offsetting production of new green tissue. Secondly, much of limpograss regrowth and all aeschynomene regrowth is from axillary buds. With grass stems trampled and matted on the soil surface, regrowth potential of the sward was limited. The effect of initiation height on legume regrowth has already been discussed.

In pasture situations, herbage accumulation is secondary in importance to herbage consumption. In 1983, there was a trend toward higher consumption with early initiation of grazing. In 1984, initiation of grazing when the legume was 20 or 40 cm tall was effective in increasing DM consumed above that observed for the 60-cm treatment. Grazing efficiency was superior at legume initiation heights of 20 or 40 cm in both years. Better utilization of forage also made pasture management decisions, i.e., the end of a grazing period, easier.

Calculations of mean botanical composition of herbage accumulated, pregraze herbage mass, and herbage consumed, suggested that animals may be selecting for aeschynomene. When the botanical composition of the upper layers of the canopy was compared to that of herbage consumed, it seemed more likely that the vertical distribution of forage species in the canopy, rather than animal selection for specific components, was influencing the botanical composition of the diet. The upper layers had a higher percentage legume than did the entire canopy (HM), but it was similar to that in herbage consumed. It should be noted that these data are for entire grazing periods, and animals may have preferred a given component and selected for it early in a grazing period.

Under conditions similar to those present during this research, aeschynomene can be successfully established into limpograss sods using only grazing management to control grass competition. Grazing the grass sod closely (approximately 8 cm) until legume seedlings are 5 cm tall (after the two-leaf stage) appears to maximize subsequent legume productivity. Initiating summer grazing early, when aeschynomene is 20 to 30 cm tall, is likely the best grazing management practice with this association. Early grazing results in more uniform accumulation of total and legume DM throughout the season, higher efficiency of grazing, more vigorous legume regrowth, and a trend toward greater total herbage consumption. A 5-week defoliation interval seems very appropriate for aeschynomene-limpograss pastures, but this research did not compare it to other intervals. Animal selection between species does not appear to be of major importance with this association, as all components were consumed in similar proportion to that observed in the upper layers of the canopy.

CHAPTER V
# FORAGE QUALITY RESPONSES OF AN *Aeschynomene americana*-*Hemarthria altissima* ASSOCIATION TO GRAZING MANAGEMENT

## Introduction

Forage quality evaluation of 'Bigalta' and 'Floralta' limpograss [*Hemarthria altissima* (Poir.) Stapf et C. E. Hubb.] has shown that these cultivars have higher concentrations of *in vitro* digestible organic matter (IVDOM) than do most other tropical grasses at similar growth stages (Quesenberry et al., 1981). Average daily gains of animals grazing N-fertilized (200 kg N $ha^{-1}$ $yr^{-1}$) Floralta, however, have not been superior to gains of animals grazing the less digestible bahiagrass (*Paspalum notatum* Flugge) (Quesenberry et al., 1984).

Euclides (1985) sampled N-fertilized limpograss pastures and found that mean crude protein (CP) concentration of the top 20 cm of the canopy was 47 g $kg^{-1}$ organic matter (OM). Crude protein concentration of esophageal extrusa of grazing steers was 58 g $kg^{-1}$ OM during the same 4-month period. Milford and Minson (1965) have reported that intake of tropical grasses declines rapidly when diet CP concentration falls below 70 g $kg^{-1}$ dry matter (DM), so one possible explanation for lower than expected animal performance on limpograss may be a protein deficiency.

Minson (1980) has suggested that the most economical way to overcome a protein deficiency in pastures is to include a legume. Aeschynomene (*Aeschynomene americana* L.) is a summer-annual legume that performs well on the large expanses of poorly drained soils in Florida, and it has shown potential for use in overseeding perennial grass pastures (Kalmbacher et al., 1978). Aeschynomene can provide high quality forage for grazing animals, with leaf tissue CP and IVDOM concentrations reported to be 250 g $kg^{-1}$ DM and 750 g $kg^{-1}$ OM, respectively (Gildersleeve, 1982).

Grazing and clipping management play a critical role in determining aeschynomene forage quality. Crude protein concentrations were 185 and 151 g $kg^{-1}$ DM for plants clipped initially at 30- and 90-cm heights (Kalmbacher et al., 1978). Delaying initial harvest reduced IVDOM concentration 80 g $kg^{-1}$ OM for each 30-cm increment of legume height (Mislevy et al., 1981). Clipping aeschynomene when it was 30 cm tall throughout the season resulted in CP and IVDOM concentrations of 175 g $kg^{-1}$ DM and 700 g $kg^{-1}$ OM, respectively (Mislevy et al., 1981). In the same study, delaying the initial cut until the legume was 90 cm, followed by one regrowth cut at 30 cm, reduced quality to 119 g CP $kg^{-1}$ DM and 525 g DOM $kg^{-1}$ OM.

Most evaluations of aeschynomene forage quality have been under clipping management. Information on forage quality responses to grazing are needed. In addition, no data are available which indicate whether associating aeschynomene with limpograss can overcome what apparently is a protein deficiency in grass-N swards. The objectives of this research were 1) to quantify the effects of grazing management on aeschynomene leaf:stem ratio, and leaf, stem, and whole plant N and IVDOM concentrations, 2) to evaluate the effects of grazing management on limpograss and total sward forage quality, and 3) to determine if overseeding of aeschynomene can eliminate a suspected protein deficiency in limpograss pastures, and if so, to suggest an effective and practical grazing management system for the association.

## Materials and Methods

An experiment was conducted in 1983 and 1984 at the University of Florida's Forage Evaluation Field Laboratory, located northeast of Gainesville, Florida (lat 29° 60' N). The research site was a 2-ha Floralta limpograss pasture that had been established in 1981. Soils were of the Pomona series (sandy, siliceous, hyperthermic Ultic Haplaquod). Prior to initiating the experiment in 1983, soil pH at the site was 5.6, and Mehlich I extractable P and K levels were 4 and 18 mg $kg^{-1}$, respectively. In 1984, mean soil pH was 5.6, and P and K levels were 6 and 34 mg $kg^{-1}$. Guided by soil test results, P and K were broadcast applied at rates of 44 and 166 kg $ha^{-1}$ in 1983, and 70 and 133 kg $ha^{-1}$ in 1984. Twenty kilograms $ha^{-1}$ of a micronutrient mixture (F-503 Oxide) were included with the P and K in both years. Lime was applied at a rate of 2.2 Mg $ha^{-1}$ in April 1984 because soil pH was nearly 5.0 in some areas of the pasture.

Experimental variables included 1) limpograss stubble height when aeschynomene was overseeded (SH), 2) legume seedling growth stage when early-season grazing was discontinued (LSGS), and 3) legume height when summer grazing was initiated. Early-season limpograss regrowth was grazed to a 7.5- or 15-cm stubble. At the onset of summer rains (7 June 1983 and 20 June 1984), dehulled, scarified, and inoculated aeschynomene seed was broadcast at a rate of 20 kg $ha^{-1}$ using a cyclone seeder. Following overseeding, cattle were rotated among the pastures to maintain the prescribed grass stubble heights. Grazing was discontinued 1) when legume cotyledons were exserted, 2) when two true leaves were present, or 3) 2 weeks after the two-leaf stage. Pastures were not grazed subsequently until the legume reached heights of 20, 40, or 80 cm in 1983 and 20, 40, or 60 cm in 1984. Following initiation of grazing at the respective heights, all pastures were grazed rotationally with a rest period of 5 weeks. Defoliation was by mob grazing to an 8- to 12-cm stubble. Exceptions were pastures where grazing was not initiated until the legume was 60 to 80 cm tall. The yearling and 2-year-old steers (Bos spp.) would not graze the mature herbage to a low stubble, so a more subjective visual appraisal of the pasture was made to determine when grazing should end.

The complete factorial set of treatments (2 x 3 x 3) was arranged in a split-split plot design in 1983 and a split-plot design in 1984. All treatments were replicated twice in each year, and pasture size was 500 $m^2$. Grass SH was the whole-plot treatment in both years, and LSGS was the subplot treatment in 1983. The design was changed in 1984 to provide a stronger test for LSGS differences, despite the original design being more convenient for animal management. Legume seedling growth stage means were compared using the single degree of freedom contrasts cotyledon vs. two-leaf stage, and cotyledon plus two-leaf stage vs. 2 weeks after the two-leaf stage. Initiation height effects were evaluated using orthogonal polynomials to determine the nature of response curves. Regression models for aeschynomene leaf-stem data did not include quadratic terms unless they were significant at $P \leqslant 0.05$.

In 1983, pastures defoliated initially when the legume was 20, 40, and 80 cm tall were grazed four, three, and two times (cycles), respectively. In 1984, both 20- and 40-cm treatments were grazed three times, and the 60-cm treatment was grazed twice. Grazing seasons for the legume-grass association extended from 11 July through 4 Nov. 1983 and 23 July through 2 Nov. 1984.

All pastures were sampled before and after each grazing period. A double sampling technique was used to determine herbage mass and sward botanical composition. It included taking visual estimates of herbage mass, percentage legume, percentage grass, and percentage weeds at five sites in each pasture. The same 0.5 $m^2$ areas were then clipped to ground level, and the fresh herbage was hand-separated into aeschynomene, limpograss, and weed components. The separated forage was dried at 60°C for 48 hours before weighing. Actual values for each response variable were calculated and regressed on visual estimates (forced through the origin). These equations were used to correct the mean of 30 visual estimates of each response variable that were taken at randomly selected locations over entire pastures. The procedure was discussed in more detail in Chapter IV.

The hand-separated botanical components were used for forage quality analyses. For each pasture at each grazing cycle there were six types of samples. These included pregraze aeschynomene, limpograss, and weeds, and postgraze aeschynomene, limpograss, and weeds. Because sampling was done at five sites pregraze and postgraze, there were five different samples of each of the six types generated each time a pasture was grazed. To simplify the analytical process, the five samples of each type (e.g., postgraze legume) were composited during grinding (weighted composites). Exceptions were the pregraze grass component in 1983, and the pregraze legume and pregraze grass components in 1984. In 1983, pregraze grass samples from each site were analyzed, and values reported are means over the five sites in a given pasture. In 1984, pasture composites were formed within species after grinding forage from pregraze legume and pregraze grass sites separately. A constant percentage of the ground forage from each site was removed and mixed with that taken from the other four sites to form the pasture composite.

For each initiation height treatment represented in the set of pastures to be grazed in a given week, two pregraze legume samples were selected for leaf-stem separation. The only restrictions to random selection were that the two samples from one height treatment could not be from the same pasture, and that there must be sufficient legume herbage to complete the analytical processes on both leaf and stem fractions. Whole plant legume samples were dried prior to leaf-stem separation, and after separation the fractions were redried overnight before weighing. The leaf fraction consisted of petiole, rachis, and leaflets. Where whole plant CP concentration is compared to that of legume leaf or stem, the whole plant value was obtained by laboratory analysis of the composited pregraze legume samples from the other four sites in that pasture.

Samples for analyses were ground to pass a 1-mm screen using a Wiley mill. In 1983, a subset of 50 samples from each sample type was selected and analyzed for N using a modification of the aluminum block digestion procedure of Gallaher et al. (1975) and for *in vitro* organic matter digestibility (IVOMD) using a modification of the two-stage technique (Moore and Mott, 1974). Nitrogen and IVOMD values for the remainder of the samples were predicted by near-infrared reflectance spectroscopy (Norris et al., 1976). In 1984, all analyses were by wet chemistry procedures as described for 1983. Legume leaf and stem samples were analyzed using wet chemistry methods in both years. Crude protein was calculated as N x 6.25.

Unless otherwise indicated, CP and IVDOM concentrations were expressed in terms of the annual accumulation of DM for the specific fraction being discussed (e.g., aeschynomene, limpograss, weeds, or total herbage). Values reported for CP and IVDOM concentration of herbage accumulated and herbage consumed were calculated using known quantities for pregraze and postgraze herbage mass, pregraze and postgraze sward botanical composition, and pregraze and postgraze component (aeschynomene, limpograss, and weeds) CP, OM, and IVDOM concentrations for each grazing cycle. For example, when calculating the CP concentration in aeschynomene herbage consumed, the first step was to calculate legume herbage consumed and legume CP consumed in each grazing cycle. Values were summed over cycles generating annual totals for legume DM and legume CP consumed. Dividing kg of legume CP consumed $ha^{-1}$ by kg of legume DM consumed $ha^{-1}$ provided a value for CP concentration in aeschynomene herbage consumed.

## Results

### Aeschynomene Leaf and Stem Quality

Forage quality responses of aeschynomene leaf and stem tissues to legume height at initiation of grazing are illustrated in Figs. 5.1 and 5.2. These data from the first grazing cycle in 1983 show that legume leaf quality was minimally affected by increasing maturity. In contrast, stem and whole plant forage quality declined markedly as initiation of grazing was delayed. Quality of aeschynomene forage consumed during grazing was consistently higher than that for pregraze whole plants, while legume herbage remaining after grazing was generally lower in quality than pregraze stem tissue.

In subsequent grazing cycles, leaf quality was not significantly affected by legume height when plants were first grazed [leaf CP = 248 + 0.48 (height), $r^2$ = 0.19; leaf IVDOM = 700 + 0.20 (height), $r^2$ = 0.03]. Leaf CP concentration remained above 230 g $kg^{-1}$ DM through the end of the season in both years, but IVDOM concentration declined to approximately 650 g $kg^{-1}$ OM during late October and early November. Stem quality was lower throughout the grazing season in pastures where initiation of grazing had been delayed [stem CP = 104 + 0.51 (height) - 0.014 $(height)^2$, $r^2$ = 0.82; stem IVDOM = 528 -2.46 (height), $r^2$ = 0.57]. Responses observed in 1984 were similar to those reported for 1983 (data not presented).

In both years, legume leaf:stem ratio decreased as initiation of grazing was delayed (Fig. 5.3). Plants that were grazed at 20-cm heights in the first cycle continued to have higher leaf:stem ratios

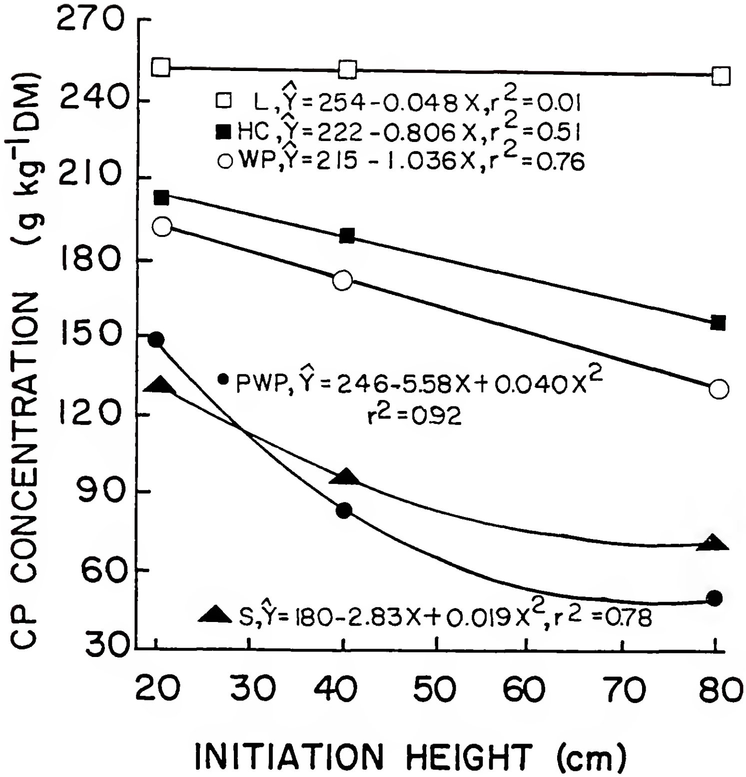


Fig. 5.1. First grazing cycle responses of aeschynomene leaf (L), stem (S), pregraze whole plant (WP), postgraze whole plant (PWP), and herbage consumed (HC) crude protein (CP) concentrations to aeschynomene height at initiation of summer grazing in 1983 (n = 20 for each response curve).

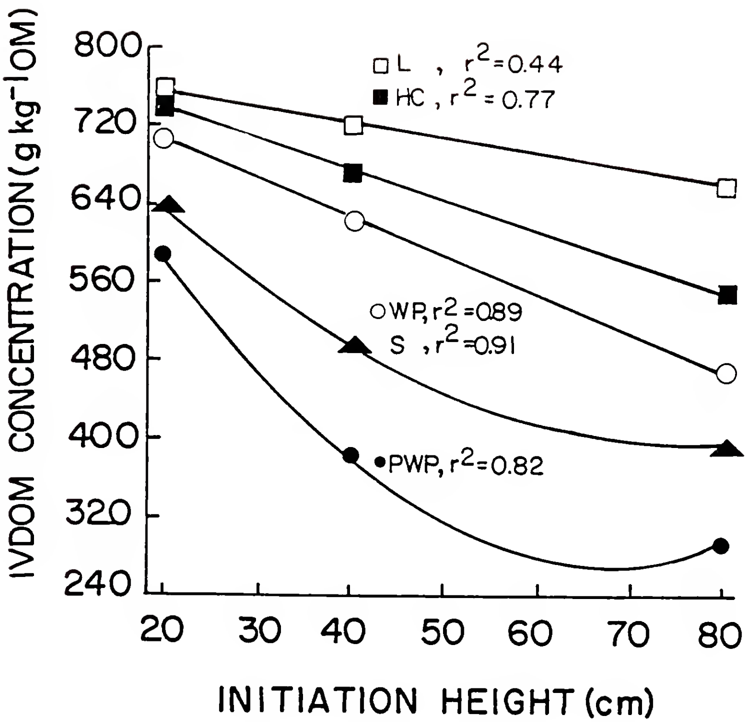


Fig. 5.2. First grazing cycle responses of aeschynomene leaf (L, $\hat{Y}$ = 769 - 1.43x), stem (S, $\hat{Y}$ = 810 - 10.07x + $0.06x^2$), pregraze whole plant (WP, $\hat{Y}$ = 780 - 3.88x), postgraze whole plant (PWP, $\hat{Y}$ = 914 - 18.89x + $0.138x^2$), and herbage consumed (HC, $\hat{Y}$ = 788 - 2.97x) *in vitro* digestible organic matter (IVDOM) concentrations to aeschynomene height at initiation of summer grazing in 1983 (n = 20 for each response curve).

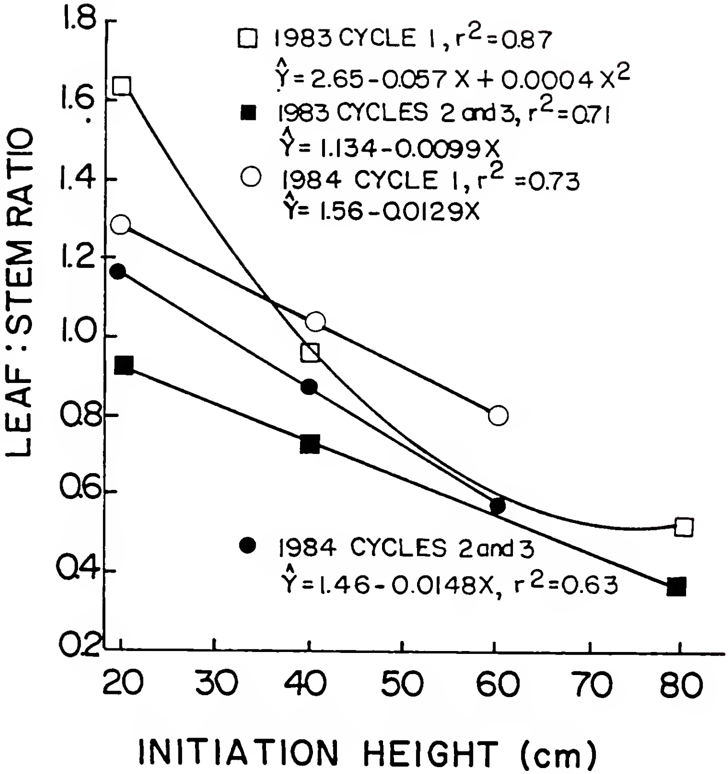


Fig. 5.3. The responses of aeschynomene leaf:stem ratio to aeschynomene height at first grazing in 1983 and 1984.

throughout the grazing season than did plants first defoliated at 40 to 80 cm (Fig. 5.3).

Whole Plant and Total Sward Canopy CP Concentrations

Limpograss CP concentration was very low in both years of the study, although in 1984 it was approximately 10 g $kg^{-1}$ DM higher than in 1983 (36 vs. 27 g CP $kg^{-1}$ DM, Table 5.1). Grass SH affected CP concentration of total grass herbage accumulated in 1983, as values for 7.5- and 15-cm treatments were 28 and 25 g $kg^{-1}$ DM ($P = 0.07$). There was no LSGS effect in 1983 ($P = 0.58$), but it was important in 1984 ($P = 0.03$). There was no SH main effect in 1984 ($P = 0.39$), but there was an SH x LSGS interaction ($P = 0.02$). The LSGS when spring grazing ended did not affect CP concentration of grass grazed to a 15-cm SH ($P = 0.18$), but limpograss CP concentrations when SH was 7.5 cm were 44, 39, and 31 g $kg^{-1}$ DM for the two leaf plus 2-weeks, two-leaf, and cotyledon treatments, respectively ($P = 0.05$ for cotyledon vs. two-leaf stage, and $P = 0.03$ for cotyledon plus two-leaf stage vs. 2 weeks after two-leaf stage). Limpograss CP concentration was significantly ($P < 0.01$), but not highly correlated with percentage legume in herbage accumulated ($r = 0.57$ in 1983 and $r = 0.55$ in 1984). Correlations were higher for the 80- ($r = 0.80$) and 60-cm ($r = 0.84$) treatments than for the 20- ($r = 0.59$ in 1983, and $r = 0.26$ in 1984) and 40-cm ($r = 0.32$ in 1983, and $r = 0.63$ in 1984) heights.

Aeschynomene CP concentration was highest in pastures defoliated initially when the legume was 20 cm tall (Table 5.1). The

Table 5.1. The effect of aeschynomene height at initiation of summer grazing (HI) on crude protein (CP) concentrations in aeschynomene (A), limpograss (LG), and total (T) herbage accumulated (HA) and herbage consumed (HC).

| | 1983 | | | | | | 1984 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | | LG | | T | | A | | LG | | T | |
| HI | HA | HC | HA | HC | HA | HC | HA | HC | HA | HC | HA | HC |
| — cm — | g CP $kg^{-1}$ DM | | | | | | | | | | | |
| 20 | 179 | 189 | 29 | 30 | 55 | 61 | 196 | 209 | 39 | 48 | 72 | 91 |
| 40 | 176 | 188 | 24 | 26 | 48 | 55 | 186 | 193 | 34 | 39 | 64 | 79 |
| 80,60† | 144 | 173 | 27 | 28 | 55 | 67 | 175 | 193 | 35 | 47 | 68 | 103 |
| SE‡ | 3.6 | 5.2 | 2.1 | 3.0 | 2.4 | 3.8 | 3.2 | 4.4 | 1.7 | 3.7 | 3.0 | 6.3 |
| F test§ | L**,Q | L* | NS | NS | NS | NS | L** | L* | NS | NS | NS | Q* |

†Aeschynomene HI was 80 cm in 1983 and 60 cm in 1984.

‡Standard error of a treatment mean.

§NS = not significant. Linear (L) or quadratic (Q) effects with probability of $P \leq 0.01$ (**), $P \leq 0.05$ (*), or $P \leq 0.10$ (letter listed, but not followed by a symbol).

establishment variables, SH and LSGS, had no effect on legume CP concentration in either year ($P \geq 0.37$).

Major weed species in the pastures included vaseygrass (Paspalum urvillei Steud.) and various sedges (Cyperus spp.). Weed forage quality was very low in 1983 and 1984, averaging 54 and 64 g CP $kg^{-1}$ DM and 440 and 380 g DOM $kg^{-1}$ OM, respectively.

Crude protein concentration in total herbage accumulated (HA) was not affected by initiation height ($P = 0.12$ in 1983, and $P = 0.15$ in 1984, Table 5.1). The SH effect was not important in 1983 ($P = 0.54$), but in 1984, CP concentration for the 7.5-cm treatment was 76 g $kg^{-1}$ DM compared to 60 g $kg^{-1}$ DM for the 15-cm treatment ($P = 0.06$). In both years, the major factor affecting CP concentration of HA was LSGS (Table 5.2). None of the LSGS treatments resulted in CP concentrations in HA greater than 70 g $kg^{-1}$ DM in 1983, and only the two leaf plus 2-weeks treatment surpassed that level in 1984.

Animals consistently selected a diet higher in CP concentration than that of HA (Tables 5.1 and 5.2). In 1983, only the two leaf plus 2 weeks LSGS treatment resulted in diet CP concentrations above 70 g $kg^{-1}$ DM. All LSGS means were greater than that level in 1984, and the two leaf plus 2-weeks treatment again resulted in the highest CP concentration in herbage consumed (HC).

Regression analysis was used to evaluate the relationship of CP concentration in HC vs. that observed in HA (Table 5.3). Equations were fit for each initiation height treatment, as height affected the response (i.e., intercepts were different between heights within a year) observed in both years ($P < 0.01$). Slopes of lines were similar

Table 5.2. The effect of aeschynomene seedling growth stage (LSGS) when establishment period grazing ended on crude protein (CP) concentration of total herbage accumulated (HA) and total herbage consumed (HC) in aeschynomene-limpograss swards.

| LSGS | 1983 HA | 1983 HC | 1984 HA | 1984 HC |
|---|---|---|---|---|
| | g CP $kg^{-1}$ DM | | | |
| Cotyledon | 43 | 47 | 59 | 75 |
| Two leaf | 54 | 63 | 64 | 86 |
| Two leaf plus 2 weeks | 62 | 72 | 81 | 112 |
| SE† | 4.0 | 5.9 | 3.0 | 6.3 |
| F test | S | S | ** | ** |
| Contrast‡ | NS,S | NS,S | NS,** | NS,** |

†Standard error of a treatment mean.
NS = not significant, S and ** indicate significance at $P \leq 0.10$ and $P \leq 0.01$.
‡Single degree of freedom contrasts of cotyledon vs. two-leaf stage, and cotyledon plus two-leaf stage vs. two leaf and 2-weeks stage.

Table 5.3. Regressions of crude protein (CP) concentration in herbage consumed (HCCP) vs. CP concentration in herbage accumulated (HACP), of HCCP vs. percentage aeschynomene in herbage accumulated (PCAHA), and of *in vitro* digestible organic matter (IVDOM) concentration in herbage consumed (HCDOM) vs. IVDOM concentration in herbage accumulated (HADOM). These data are for aeschynomene-limpograss swards for 1983 and 1984, and separate regression equations were fit for each aeschynomene height at initiation of summer grazing (HI).

| Dependent variable | HI | Intercept | | b | | Independent variable | $r^2$ | | Minimum X† | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1983 | 1984 | 1983 | 1984 | | 1983 | 1984 | 1983 | 1984 |
| HCCP | 20‡ | -8.0 | -10.6 | 1.24 | 1.41 | HACP | 0.96 | 0.94 | 62.9 | 57.2 |
| | 40 | -12.2 | 7.1 | 1.38 | 1.13 | | 0.96 | 0.91 | 56.9 | 55.7 |
| | 80,60§ | -6.2 | -29.8 | 1.33 | 1.95 | | 0.96 | 0.98 | 57.3 | 51.2 |
| HCCP | 20 | 38.1 | 48.2 | 1.95 | 2.68 | PCAHA | 0.66 | 0.88 | 16.4 | 8.1 |
| | 40 | 29.9 | 38.5 | 2.59 | 2.92 | | 0.83 | 0.84 | 15.5 | 10.8 |
| | 80,60 | 17.8 | 37.8 | 2.32 | 3.10 | | 0.85 | 0.90 | 22.5 | 10.4 |
| HCDOM | 20 | -173 | -235 | 1.41 | 1.52 | HADOM | 0.78 | 0.94 | -- | -- |
| | 40 | -378 | -150 | 1.82 | 1.38 | | 0.57 | 0.62 | -- | -- |
| | 80,60 | 168 | -80 | 0.79 | 1.30 | | 0.40 | 0.68 | -- | -- |

†Minimum X is the value of the independent variable that is predicted to result in HCCP of 70 g $kg^{-1}$ DM.

‡There were 12 data points for each equation, regardless of HI.

§HI was 80 cm in 1983 and 60 cm in 1984.

over all heights in 1983 ($P = 0.74$), but in 1984 slopes varied between heights ($P < 0.01$). The regression of CP concentration in HC vs. percentage legume (% L) in HA was also of interest (Table 5.3). In 1983, height effects were significant ($P < 0.01$), but slopes of the response curves for height were not different ($P = 0.67$). There were no height effects ($P = 0.32$) and slopes were similar ($P = 0.60$) in 1984, and a single equation [$y = 40.7 + 2.96$ (% L), $r^2 = 0.89$] could replace those listed in Table 5.3 for this relationship.

## Whole Plant and Total Sward Canopy IVDOM Concentrations

Concentrations of IVDOM in limpograss and total HA decreased linearly in both years as initiation of grazing was delayed (Table 5.4). No experimental variable other than initiation height affected grass or total herbage IVDOM concentrations in either year.

Initiation height was also the only experimental variable affecting aeschynomene IVDOM concentration. Linear and quadratic effects were important in both years (Table 5.4).

Animal selection for forage with higher IVDOM concentration was evident (Table 5.4). Differences in IVDOM concentration of HC were small to negligible between 20- and 40-cm treatments in both years. In 1984, there were no differences in IVDOM concentration of total HC due to initiation height. Relationships between IVDOM concentrations in HC (HCDOM) and in HA (HADOM) are indicated in Table 5.3. Initiation height affected the response (intercepts) in 1984 ($P = 0.06$) but not in 1983 ($P = 0.16$). Slopes of these responses did not vary between heights ($P = 0.12$ in 1983, and $P = 0.83$ in 1984).

Table 5.4. The effect of aeschynomene height at initiation of summer grazing (HI) on *in vitro* digestible organic matter (IVDOM) concentrations in aeschynomene (A), limpograss (LG), and total (T) herbage accumulated (HA) and herbage consumed (HC).

| | 1983 | | | | | | 1984 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | | LG | | T | | A | | LG | | T | |
| HI | HA | HC | HA | HC | HA | HC | HA | HC | HA | HC | HA | HC |
| — cm — | g IVDOM $ka^{-1}$ OM | | | | | | | | | | | |
| 20 | 616 | 643 | 597 | 640 | 562 | 618 | 643 | 669 | 580 | 615 | 547 | 598 |
| 40 | 611 | 648 | 582 | 648 | 549 | 623 | 618 | 638 | 566 | 603 | 533 | 588 |
| 80,60† | 516 | 595 | 532 | 579 | 496 | 563 | 559 | 603 | 548 | 599 | 508 | 580 |
| SE‡ | 10.8 | 11.0 | 8.1 | 17.2 | 7.2 | 12.1 | 6.9 | 8.4 | 9.4 | 20.4 | 11.8 | 19.1 |
| F test§ | L**,Q | L** | L** | L* | L** | L** | L**,Q | L** | L* | NS | L* | NS |

†Aeschynomene HI was 80 cm in 1983 and 60 cm in 1984.

‡Standard error of a treatment mean.

§NS = not significant. Linear (L) or quadratic (Q) effects with probability of $P \leqslant 0.01$ (**), $P \leqslant 0.05$ (*), or $P \leqslant 0.10$ (letter listed, but not followed by a symbol).

The regression equation over all heights in 1983 was HCDOM = 69 + 0.99 (HADOM), ($r^2 = 0.67$).

The effects of initiation height on organic matter accumulated (OMA), digestible organic matter accumulated (DOMA), and digestible organic matter consumed (DOMC) are shown in Table 5.5. The tallest initiation height treatment (80 or 60 cm) was superior to the 20-cm treatment in OMA, not different in DOMA, and inferior in DOMC in both years.

## Discussion

Hodges et al. (1982) stated that aeschynomene is capable of providing high quality forage for grazing during mid- to late-summer, a crucial period when perennial grass quality does not meet the needs of lactating beef cows or grazing calves. Data from the current research support this conclusion. Aeschynomene leaves had CP and IVDOM concentrations of 250 g $kg^{-1}$ DM and 700 g $kg^{-1}$ OM during the majority of the period from July through October. These values are similar to those reported for aeschynomene by Gildersleeve (1982). Gildersleeve also detected a drop in leaf IVDOM concentration as temperatures decreased late in the season. A similar response was observed in late October and early November in the current study, and IVDOM concentration dropped from approximately 700 to 650 g $kg^{-1}$ OM.

In contrast to aeschynomene leaf quality, which was minimally affected by grazing management, stem CP and IVDOM concentrations showed marked responses to legume height when plants were first grazed. Stem quality was always lower than that of leaf, and delaying

Table 5.5. The effect of aeschynomene height at initiation of summer grazing (HI) on organic matter accumulation (OMA), *in vitro* digestible organic matter accumulation (DOMA), and *in vitro* digestible organic matter consumption (DOMC) of aeschynomene-limpograss associations.

| HI | 1983 OMA | 1983 DOMA | 1983 DOMC | 1984 OMA | 1984 DOMA | 1984 DOMC |
|---|---|---|---|---|---|---|
| — cm — | Mg $ha^{-1}$ | | | | | |
| 20 | 8.06 | 4.52 | 3.68 | 6.48 | 3.54 | 2.35 |
| 40 | 7.79 | 4.27 | 3.22 | 7.35 | 3.92 | 2.72 |
| 80, 60† | 9.21 | 4.58 | 3.20 | 7.09 | 3.62 | 2.04 |
| SE‡ | 0.30 | 0.15 | 0.15 | 0.21 | 0.14 | 0.11 |
| F test§ | L**,Q | NS | L | L,Q* | NS | L,Q** |

†Aeschynomene HI was 80 cm in 1983 and 60 cm in 1984.

‡Standard error of a treatment mean.

§NS = not significant. Linear (L) or quadratic (Q) effects with probability of $P \leqslant 0.01$ (**), $P \leqslant 0.05$ (*), or $P \leqslant 0.10$ (letter listed, but not followed by a symbol).

initiation of grazing resulted in further reductions in stem CP and IVDOM concentrations. This was the case both in cycle 1 and throughout the remainder of the grazing season.

Aeschynomene leaf:stem ratio was highest in cycle 1 and in subsequent grazings for plants that were initially defoliated at 20-cm heights. Mislevy et al. (1981) reported that stem diameters of aeschynomene regrowth (90 cm tall) were 50 to 75% smaller if plants were initially clipped at 30 instead of 90 cm. They indicated that early clipping resulted in high leaf:stem ratio and good forage quality in all regrowth harvests. Gildersleeve (1982) observed that plants grazed initially at 28 cm made vigorous regrowth throughout the season and had higher leaf:stem ratios than did plants that were first grazed at 45- or 54-cm heights.

Animals preferred aeschynomene leaf over stem. This is indicated as the quality of the legume consumed was higher than that in pregraze whole plants. Gildersleeve (1982) reported that cattle will graze aeschynomene leaf and fine stems (less than 4 mm in diameter). Under heavy grazing in the current study, substantial amounts of higher quality stem were consumed. This is apparent because the quality of postgraze legume was generally lower than that of pregraze stem.

Maintaining adequate legume stands and high legume forage quality were critical throughout the season because limpograss CP concentration was well below the minimum of 70 g $kg^{-1}$ DM suggested by Milford and Minson (1965). Limpograss CP concentration was slightly higher in the 7.5-cm SH treatment in 1983, likely due to a greater proportion of new growth in cycle 1 whole plant samples. In 1984, the

CP concentration of grass grazed to the 7.5-cm SH responded to LSGS. Pastures grazed for the longest period of time following seeding of the legume had highest limpograss CP concentrations. This also may be related to a greater proportion of less mature grass regrowth in cycle 1 samples, but it should be noted that percentage legume in sward DM also increased with longer periods of spring grazing (Table 4.3). In fact, limpograss CP was correlated, although not highly, with percentage legume in both years of the study.

It has been well established that perennial legumes do supply N to associated grasses in temperate regions (Sollenberger et al., 1984). Whether a tropical, summer-annual legume growing in sandy soils can make a significant contribution of N to a grass is subject to debate. It is noted that correlations between limpograss CP and percentage aeschynomene in sward DM were highest at the 80- and 60-cm initiation heights. Some of this response may be related to high legume mortality in these treatments after initial defoliation. Death and decomposition of well-established, well-nodulated legume plants would likely result in release of N to the associated grass. Other factors may be involved. In a small-plot clipping trial that was harvested once at the end of the growing season (Chapter III), the correlation between limpograss CP concentration and percentage aeschynomene in sward DM (r = 0.84) was similar to that observed for the 60- and 80-cm treatments in this study. In both the clipping and grazing studies there were many aeschynomene leaflets dropped from taller, more mature plants. Whitney et al. (1967) suggest that some of the transfer of N from Centrosema pubescens Benth. to Pennisetum purpureum Schumach. was the result of leaf drop. No firm conclusions can be drawn, but these observations suggest that if aeschynomene is permitted to grow without being grazed over an extended period, it may supply appreciable quantities of N to an associated grass. Early and frequent defoliation (5-week intervals) may limit this supply because plants lose fewer leaflets, they are more persistent, and they are given less time to develop N-fixing capabilities before being subjected to the stress of defoliation. From a practical management perspective, however, there are advantages to early initiation of grazing, and aeschynomene probably cannot be counted on to supply large quantities of N to limpograss.

The major contribution of aeschynomene to these swards was its own N-rich herbage. In both years of the study, there were strong relationships between the CP concentration of HC (HCCP) and the percentage aeschynomene in HA. The major factor affecting both of these response variables was LSGS. During aeschynomene establishment, extending the period of time that grass competition was controlled by grazing increased observed values for HCCP and for percentage legume in sward DM. These data in general, and particularly those from 1983, indicate that grazing management during establishment was critical if sward CP concentrations were to be above levels where intake and animal performance are not limited.

Regression of HCCP vs. percentage legume in HA showed that 16 to 23% and 8 to 11% aeschynomene were required in 1983 and 1984 if HCCP was to be 70 g $kg^{-1}$ DM or above. Gomes (1978) reported that CP concentration of a Bigalta-aeschynomene association under clipping management was greater than 70 g $kg^{-1}$ DM only if percentage legume was higher than 20%. In the current study, differences between years in percentage legume required were likely related to higher CP concentrations in aeschynomene, limpograss, and weed components in 1984. This may have been due to nutrient recycling of legume residues and animals wastes from the 1983 grazing season. In 1982, grazing of the area was very lax and the legume was not present. In addition, pastures were burned prior to initiating the experiment in 1983 only. Approximately 90% of N in residue is lost to the atmosphere during a burn (Norman and Wetselaar, 1960), and this may have contributed to the apparent low N status of these soils in 1983. In both years the CP concentration of HA necessary for HCCP to be 70 g $kg^{-1}$ DM was approximately 55 to 60 g $kg^{-1}$ DM.

Concentrations of IVDOM were generally more closely related to changes in initiation height than were CP concentrations. This was true for legume leaf and stem fractions as well as for most whole-plant data. The general nature of the IVDOM response to height was similar to that for CP concentration, and pastures where grazing was initiated early had higher herbage IVDOM concentrations. Higher concentrations of IVDOM and higher efficiency of grazing in the 20-cm treatment resulted in greater consumption of IVDOM for that treatment than that observed for the 80- or 60-cm heights. This occurred despite the fact that the tallest treatments were superior in total herbage OM accumulation.

Under the conditions of this experiment, aeschynomene provided high quality forage for grazing during what is typically referred to as the "summer slump" period in Florida. Some grazing management practices resulted in sufficient aeschynomene in the association to increase diet CP concentrations above 70 g $kg^{-1}$ DM. It must be stressed, however, that grazing management is critical to the success of this association. Grass competition must be controlled during establishment for subsequent legume stands to be adequate. One approach to grass control appears to be grazing the grass to a 7.5-cm stubble until legume seedlings are approximately 5 cm tall. Data from this research suggest that summer grazing of the association should begin when the legume is 20 to 30 cm tall. Early initiation of grazing appears to result in highest N and IVDOM concentrations in forage, more rapid aeschynomene regrowth with a higher leaf:stem ratio, and greater consumption of digestible organic matter $ha^{-1}$.

CHAPTER VI
SEED PRODUCTION RESPONSES OF
*Aeschynomene americana* TO GRAZING MANAGEMENT

## Introduction

Aeschynomene (*Aeschynomene americana* L.) is the most widely adapted warm-season legume available for grazing in Florida (Hodges et al., 1982). The legume can provide high quality forage for cattle during mid to late summer (Chapter V), a time when most perennial grasses are unable to sustain satisfactory levels of animal performance.

Aeschynomene is a summer-annual legume, so it is dependent upon natural reseeding to persist from year to year. The legume is capable of producing large quantities of seed (Hodges et al., 1982), but few studies have evaluated aeschynomene seed production under grazing.

Humphreys (1980) indicated that forage legume seed production responses to defoliation may be favorable or adverse, depending upon the effects of grazing on inflorescence density, assimilate supply to the developing inflorescence, timing and duration of flowering, and control of competing species. Gildersleeve (1982) reported higher aeschynomene seed yields $ha^{-1}$ if grazing was initiated when plants were 28, rather than 45 or 54 cm tall. The author suggested that early grazing removed apical dominance, stimulated axillary bud development and branching, and provided more sites for inflorescences. Similar observations were made with *Stylosanthes hamata* (L.) Taub.

(Wilaipon et al., 1979). Pitman and Kalmbacher (1983) reported that aeschynomene seed production was greatest if fall grazing ended before flowering. Unfortunately, cessation of grazing during vegetative growth left large quantities of legume herbage unutilized.

The objectives of this research were 1) to determine the effects of plant height at first grazing and closure date of fall grazing on aeschynomene seed production, and 2) to quantify the amount of unutilized herbage dry matter resulting from these treatments.

## Materials and Methods

An experiment was conducted in 1983 and 1984 at the University of Florida's Forage Evaluation Field Laboratory located northeast of Gainesville, Florida. The research site was a 2-ha aeschynomene-'Floralta' limpograss [*Hemarthria altissima* (Poir.) Stapf et C. E. Hubb.] pasture on a typical flatwoods soil of the Pomona series (sandy, siliceous, hyperthermic Ultic Haplaquod). Prior to initiating the experiment in 1983, soil pH at the site was 5.6, and Mehlich I extractable P and K levels were 4 and 18 mg $kg^{-1}$, respectively. In 1984, mean soil pH was 5.6, and P and K levels were 6 and 34 mg $kg^{-1}$. Guided by soil test results, P and K were broadcast applied at rates of 44 and 166 kg $ha^{-1}$ in 1983, and 70 and 133 kg $ha^{-1}$ in 1984. Twenty kilograms $ha^{-1}$ of a micronutrient mixture (F-503 Oxide) were included with the P and K in both years. Lime was applied at a rate of 2.2 Mg $ha^{-1}$ in April 1984 because soil pH was nearly 5.0 in some areas of the pasture. Due to extreme drought, all experimental units were hand-watered with the equivalent of 50 mm of water on 25 Sept. 1984.

Actual rainfall at the site was 445 and 158 mm from August through October in 1983 and 1984, respectively. The 70-year mean for the site is 447 mm during these months.

The current experiment was superimposed upon a large-scale grazing evaluation of an aeschynomene-limpograss association. Materials and methods for the grazing experiment were previously described (Chapter IV).

Experimental variables in the current research were aeschynomene height when summer grazing was initiated and date when fall grazing of the legume ceased (closure date). The legume was defoliated initially at heights of 20, 40, or 80 cm in 1983, and 20, 40, or 60 cm in 1984. Fall grazing ended approximately 1 week before flowering (BF), at first flower (F), or 2 weeks after first flower (AF) in both years. In addition to the treatments already described, seed production was quantified for aeschynomene plants that were not defoliated during the entire growing season. The rotational grazing system used in the associated grazing trial prohibited defoliation from ending on the specific closure dates in some cases. Consequently, closure date was treated as a continuous variable for statistical analysis. To simplify the description of experimental methods, reference will continue to be made to three distinct levels of closure date.

Following initiation of grazing at the respective legume heights, pastures were rotationally grazed with a rest period of 5 weeks. Defoliation was by mob grazing to a stubble of 10 to 15 cm except when grazing was initiated at 60 or 80 cm. Animals consumed leaves and the less woody terminal portions of the stems of these mature plants, but they would not graze to a low stubble. Regardless of plant height at initiation, little leaf remained following each grazing.

For a given closure date (BF, F, or AF), four, 1-$m^2$ sites were selected in pastures of each initiation height. Four sites had also been chosen for the ungrazed control before grazing was initiated, so there were a total of 40 sites included in the study. Anchored, wire-mesh cages prohibited animal access to these areas. Sites were selected that were representative of specific pastures in both botanical composition and residual herbage mass. Legume stand density varied widely for pastures within a given height treatment due to grazing management at establishment (Chapter IV). Consequently seed yield was calculated on a per plant basis for all treatments.

First flower was observed on 29 Sept. 1983 and 15 Sept. 1984. Sites for the ungrazed control and treatments BF, F, and AF were harvested on 18 Nov., 28 Nov., 28 Nov., and 2 Dec. 1983, and on 6 Nov., 6 Nov., 13 Nov., and 20 Nov. 1984, respectively. The inner 0.5-$m^2$ circle of each 1-$m^2$ caged area was sampled. Plants were cut to ground level with battery powered shears when most seedpods were brown, but before many fell to the ground. The cut forage was hand-separated into grass, legume, and legume seed fractions, dried at 60°C for 72 hours, and dry weights were recorded. Legume plants were counted in each experimental unit, so that seed production could be compared on a per plant basis. Pods were not removed from the seed so values reported are mg of dry seed in the hull $plant^{-1}$.

The effect of closure date, initiation height, and the closure x height interaction were determined using the heterogeneity of slopes method (Freund and Littell, 1981). The authors describe testing for heterogeneity of slopes as a natural extension of covariance analysis. With the current data, covariance tested for differences in height intercepts (i.e., for each level of initiation height the response variable was regressed on closure date, and the intercepts of the three height regressions were compared), assuming that the regression relationships (slopes) among heights were not different. Heterogeneity of slopes tested the validity of this assumption by determining whether or not the regression coefficients were constant for the three height treatments. If slopes were found to be different this indicated a significant interaction.

## Results

### Seed Production

In both 1983 and 1984 seed production plant$^{-1}$ decreased as closure date was delayed ($P < 0.01$). There was no effect of initiation height on seed production in either year ($P = 0.21$ in 1983, and $P = 0.84$ in 1984), and the slopes of the three height responses were similar within years ($P = 0.54$ in 1983, and $P = 0.80$ in 1984).

Because the height effect was not significant, all heights were combined to develop a single response curve relating seed production plant$^{-1}$ to closure date for each year (Fig. 6.1). In 1983, seed production plant$^{-1}$ decreased most rapidly when grazing continued during the 2 weeks preceding first flower. In contrast, seed

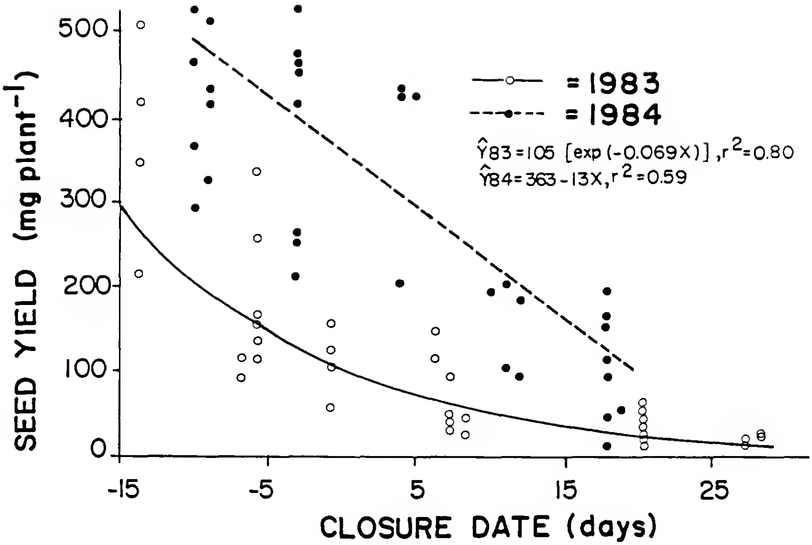


Fig. 6.1. The response of aeschynomene seed yield plant$^{-1}$ in 1983 and 1984 to closure date of fall grazing. Negative closure dates are days before first flower, and positive closure dates are days after first flower when grazing ended.

production decreased at a more uniform rate over time in 1984, as evidenced by the linear function. For these curves and all others that have closure date as the independent variable, a closure of zero means that grazing ended at first flower, while a negative or a positive closure date indicate the number of days before or after flowering, respectively, that grazing ended.

Mean seed DM plant$^{-1}$ of the ungrazed control was compared with the least squares mean (i.e., adjusted for covariance) of the grazing treatments using a t test. Grazing reduced seed production plant$^{-1}$ in both years ($P < 0.01$). Estimates of seed production ha$^{-1}$ were calculated (g seed 0.5 m$^{-2}$ x 20 to convert to kg seed ha$^{-1}$) for the control, for all sites where actual closure date was before flowering, and for all sites where closure date was after flowering (Table 6.1). These data were not adjusted for the closure date covariate, and statistical comparisons were not deemed appropriate. They are presented to show general trends only.

## Accumulation of Ungrazed Herbage

In 1983 there was no effect of initiation height on the amount of ungrazed herbage ($P = 0.55$), and slopes for the regressions of total ungrazed DM vs. closure date were similar for all heights ($P = 0.59$). Data were combined over heights, and the regression of ungrazed DM vs. closure date showed that ungrazed DM decreased linearly as closure was delayed ($y = 3.60 - 0.048$ x closure date, $r^2 = 0.54$).

In 1984, both the height effect ($P = 0.05$) and the heterogeneity of slope test ($P < 0.01$) were significant. Regression lines for the

Table 6.1. Mean aeschynomene seed production (unadjusted for closure date) for sites that were ungrazed (U), that were last grazed before flowering (BF), or that were last grazed after flowering (AF).

| Response | 1983 | | | 1984 | | |
|---|---|---|---|---|---|---|
| | U† | BF | AF | U | BF | AF |
| Seed $plant^{-1}$ (mg)‡ | 650 | 200 | 50 | 930 | 440 | 200 |
| Seed $ha^{-1}$ (kg) | 480 | 95 | 22 | 1170 | 510 | 96 |

†Data for the ungrazed control are means of four sites. Before flowering and after flowering data are means of 16 and 20 sites, respectively in 1983, and 18 sites in 1984.

‡Seed production is expressed as units of dried seed including the pod (hull).

three heights are plotted in Figure 6.2. The quantity of ungrazed herbage in the 60-cm treatment declined more slowly in response to delaying closure date than did that for the 20- or 40-cm initiation height.

## Discussion

Aeschynomene exhibits a short-day floral initiation habit, and flowering typically begins about 10 September in north-central Florida (Quesenberry and Ocumpaugh, 1981). Because a number of ecotypes are represented by Florida common aeschynomene, seed purchased in different years may be of different ecotypes, and flowering date will likely vary somewhat as a result. In 1983, flowering began on 29 September as compared to 15 September in 1984. Delayed flowering in 1983 may have contributed to lower seed yields as some seed set occurred in November when temperatures were lower (Table 6.2). When seed set of *Stylosanthes humilis* H. B. K. occurred under conditions of decreased temperature and radiation, the proportion of florets setting seed was greatly reduced (Loch and Humphreys, 1970).

*Selenisa sueroides* (Guenee) [formerly *Selenus monotropa* (Grote), identification by Dr. Dale Habeck, IFAS Entomology] populations were very high during seed set in 1983. These caterpillars appeared to favor aeschynomene flowers and immature pods to leaf tissue, and they were very prevalent at stem and branch terminals. The population was not quantified, and no control measures were taken. Feeding by *S. sueroides* appeared to be the major cause of lower seed yields in 1983 than in 1984. This caterpillar has previously been identified as a

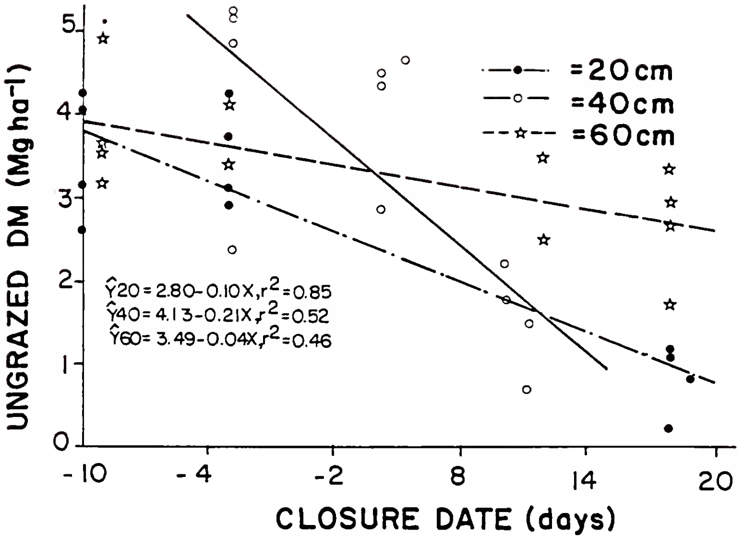


Fig. 6.2. The response of ungrazed dry matter (DM) remaining at seed harvest to closure date for 20-, 40-, and 60-cm initiation height treatments (1984). Negative closure dates are days before first flower, and positive closure dates are days after first flower when grazing ended.

Table 6.2. Mean high and low temperatures for 15-day periods from 1 Sept. to 30 Nov. 1983 and 1984.

| Year | Period† 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| | °C | | | | | |
| 1983 | 30–15‡ | 26–13 | 30–16 | 26–13 | 24–11 | 23–5 |
| 1984 | 31–14 | 29–18 | 27–13 | 31–17 | 23– 8 | 23–7 |

†Periods 1 through 6 correspond to 1 to 15 Sept., 16 to 30 Sept., 1 to 15 Oct., 16 to 31 Oct., 1 to 15 Nov., and 16 to 30 Nov.
‡Data recorded at the Beef Research Unit, northeast of Gainesville, Florida.

leaf and stem feeder of aeschynomene (Kretschmer and Bullock, 1980). Velvetbean caterpillars (Anticarsia gemmatalis Hubner) were also observed feeding on aeschynomene, but they consumed only leaf tissue, and populations were so small that little damage resulted. In 1984, S. sueroides was not present in the pastures, and field observations (no data taken) suggested a higher proportion of florets setting seed and fewer immature pods suffering damage.

Initial height of defoliation had no effect on aeschynomene seed production plant$^{-1}$. Gildersleeve (1982) achieved higher seed yields ha$^{-1}$ by initiating grazing at 28 vs. 45 or 54 cm. An important factor in seed yield per unit land area is stand density. Gildersleeve (1982) and Sollenberger et al. (1985) reported better aeschynomene persistence and more vigorous regrowth when plants were initially defoliated at 20 to 28 cm. Thus, grazing early may not increase seed production plant$^{-1}$, but a combination of comparable seed DM plant$^{-1}$ and higher stand density may favor the early initiation height treatments in seed production ha$^{-1}$.

Closure date is generally an important factor affecting seed production. In Stylosanthes hamata, defoliation at vegetative or early floral stages did not decrease inflorescence density, because it increased the rate of branching and provided more sites for inflorescences to develop (Wilaipon and Humphreys, 1976). In Stylosanthes guyanensis (Aubl.) Sw., defoliation 30 days before floral initiation did not change inflorescence density, but continuing grazing beyond that stage reduced subsequent seed yields (Loch et al., 1976). Pitman and Kalmbacher (1983) obtained highest aeschynomene seed yields if defoliation ended during vegetative growth. Continuing grazing through first flower reduced seed yield from 280 to 180 kg $ha^{-1}$, and if grazing did not cease until 27 days after flowering, seed yield fell to 128 kg $ha^{-1}$.

In the current study, seed production $plant^{-1}$ declined as closure date was delayed. Selective grazing of leaves and stem tips by the cattle left little leaf tissue and few inflorescences remaining after defoliation. Regeneration of both photosynthetic tissue and inflorescences were required after grazing, indicating that defoliation may have adversely affected inflorescence density and supply of assimilate to developing inflorescences. The plants also were required to set seed later in the season, a time when colder temperatures were more likely.

Accumulation of ungrazed herbage also was affected by grazing management. The most important factor affecting herbage accumulation was closure date. Early closure increased seed production $plant^{-1}$, but it also resulted in greater quantities of forage being unutilized. Similar results have been reported by Pitman and Kalmbacher (1983), suggesting that forage producers will need to compromise between maximum forage utilization and maximum seed production.

These data support the conclusions of other researchers that aeschynomene can produce large quantities of seed under grazing (Gildersleeve, 1982; Hodges et al., 1982). Grazing decreased seed production from levels observed for undefoliated plants, possibly by decreasing inflorescence density, by decreasing assimilate supply to inflorescences, and by delaying seed set to periods of time when climatic conditions were less favorable. Aeschynomene height when grazing was initiated appears to affect seed production $ha^{-1}$ through its effect on stand density and not by affecting seed production $plant^{-1}$. The pasture manager will likely need to compromise between the need for quality forage in late summer and early fall and the requirement of high aeschynomene seed yields for adequate stand regeneration the following year. Based on these data, removal of cattle at first flower and allowing plants to set seed before additional grazing may be a satisfactory compromise.

# CHAPTER VII
# SUMMARY AND CONCLUSIONS

A series of experiments were conducted in 1983 and 1984. Objectives of this research were 1) to evaluate aeschynomene (*Aeschynomene americana* L.) establishment in 'Floralta' limpograss [*Hemarthria altissima* (Poir.) Stapf et C. E. Hubb.] sods using several management strategies and under a range of environmental conditions, 2) to determine the effects of grazing management on aeschynomene and total sward productivity, pasture botanical composition, and forage quality of the association, and 3) to compare grazing management effects on aeschynomene seed production.

## Aeschynomene Establishment

The primary factors affecting aeschynomene establishment in Floralta limpograss sods appear to be soil temperature and soil moisture status at seeding, rainfall during the 2 to 3 weeks following seeding, and control of grass competition. Soil temperatures may be limiting through approximately 20 April in north Florida, but no data are available that indicate a critical temperature for aeschynomene germination and emergence. After this date, failure to achieve adequate legume seedling emergence was mainly due to poor soil moisture conditions. Spring seedings were successful if soils were moist at planting, and if the seed was incorporated into the soil. Broadcast seedings at this time were not successful because little or no rain fell subsequently and few seedlings emerged. In general, spring seeding is more risky because rainfall is often minimal during this period. The risk can be lessened somewhat by using at least 14 kg hulled seed $ha^{-1}$ and by incorporating the seed into the soil. Extended drought in late April and May can still be very detrimental, particularly to young seedlings whose roots have not penetrated deeply into the soil profile.

Even if germination and emergence were excellent and soil moisture adequate, subsequent aeschynomene productivity was minimal if grass competition to developing seedlings was not controlled. Limpograss sods can be made less competitive by applying herbicide, by tillage (light disking followed by cultipacking) at time of seeding, and by grazing until aeschynomene seedlings are approximately 5 cm tall (2 weeks after the two-leaf stage). The most practical options in Florida pastures appear to be tillage and/or grazing. Extending grazing after aeschynomene cotyledons are exserted results in loss of plants from the stand, so cattle should have access to pastures only for the time required to maintain the desired grass stubble height.

## Productivity and Forage Quality of Aeschynomene, Limpograss, and Their Association

Aeschynomene dry matter (DM) accumulation and percentage legume in total DM accumulated tended to be higher for the 7.5- than for the 15-cm stubble height treatment. Extending establishment period grazing beyond the aeschynomene two-leaf stage also increased subsequent legume productivity. Aeschynomene DM accumulation was greatest if grazing was initiated when aeschynomene was 80 (1983) and

60 cm (1984) tall. Almost all of this DM was accumulated in cycle 1, as a majority of the stand was lost after the first grazing, and regrowth from surviving plants was minimal. Initiating grazing when the legume was 20 cm tall improved legume persistence and the distribution of legume herbage over the season. In 1983, the 80-cm treatment accumulated 95% of its seasonal total of aeschynomene DM in cycle 1, while the 20-cm treatment accumulated 56% in cyles 1 and 2 and 44% in cycles 3 and 4. Other advantages for early initiation of grazing include more vigorous legume regrowth, higher efficiency of grazing, and a trend toward greater total herbage consumption.

Percentage legume in herbage consumed was consistently higher than that in herbage accumulated, suggesting that animals were selecting for aeschynomene. Stratified clipping of the grass-legume canopy showed that the proportion of legume in the diet was similar to that in the upper layers of the sward. This indicates that animals were probably not selecting for one species over another during a complete grazing period, although they may have preferred a given component and selected for it early in a grazing period.

Cattle did select strongly for aeschynomene leaf tissue over stem, as evidenced by higher concentrations of crude protein (CP) and *in vitro* digestible organic matter (IVDOM) in legume herbage consumed than in pregraze legume whole plant samples. Leaf CP and IVDOM concentrations were approximately 250 g $kg^{-1}$ DM and 700 g $kg^{-1}$ OM throughout the season. Forage quality of aeschynomene leaf (including petiole, rachis, and leaflets) was minimally affected by grazing management, but aeschynomene stem markedly decreased in quality as initiation of grazing was delayed. Legume leaf:stem ratio also decreased with increasing maturity. Plants grazed initially at 20-cm heights had higher leaf:stem ratios in the first grazing cycle and throughout the season than did plants initially grazed at taller heights.

Limpograss CP concentration was very low, ranging from 25 to 40 g $kg^{-1}$ DM. As a result, only those treatments that produced good legume stands increased the CP concentration of herbage consumed to above 70 g $kg^{-1}$ DM. The percentage legume in sward DM necessary to achieve this objective ranged from 16 to 23% in 1983 and 8 to 11% in 1984.

Highest concentrations of IVDOM were associated with the 20-cm treatment. That advantage plus a greater efficiency of grazing meant that although the 20-cm treatment accumulated less OM than did 80- or 60-cm treatments, the consumption of IVDOM was superior for the 20-cm initiation height.

## Aeschynomene Seed Production

Aeschynomene seed yield $plant^{-1}$ was not affected by legume height at initiation of grazing, but it was strongly influenced by closure date of fall grazing. Continuing to graze the legume into its reproductive phase led to marked declines in seed DM $plant^{-1}$. Seed yield $plant^{-1}$ was lower in 1983 than in 1984 mainly due to *Selenisa sueroides*. This caterpillar fed extensively on flowers and immature seedpods of the legume in 1983, but it was not present in 1984.

## Implications of the Research

The results of these experiments suggest that with careful management aeschynomene can be successfully established into perennial grass sods. Once established the legume is capable of making significant contributions to overall sward forage quality, particularly in N-deficient grass pastures. Aeschynomene can produce large quantities of seed if fall grazing is discontinued at or before flowering, but this practice limits herbage available to grazing animals during a critical period of the year. Consequently, the benefit of fall grazing must be evaluated against the cost of reseeding aeschynomene pastures annually.

Floralta limpograss CP concentration was very low in these experiments. This attribute may limit its acceptance and use in Florida. The aeschynomene-limpograss association has definite potential for wet flatwoods soils, but animal production data are needed to help determine if the legume can overcome the CP deficiency of the grass throughout the grazing season.

APPENDIX

Table A-1. The effect of aeschynomene seeding rate on numbers of aeschynomene seedlings in limpograss sods at 10, 20, 30, and 60 days after seeding (1983).

| Rate | Days after seeding | | | |
|---|---|---|---|---|
| | 10 | 20 | 30 | 60 |
| $kg\ ha^{-1}$ | seedlings $m^{-2}$ | | | |
| 7 | 60 | 59 | 50 | 45 |
| 14 | 119 | 113 | 95 | 88 |
| SE† | 7.8 | 6.3 | 5.7 | 5.9 |
| F test‡ | ** | ** | ** | ** |

†Standard error of a treatment mean.
‡** indicates probability level of $P \leqslant 0.01$.

Table A-2. Legume seeding date x establishment method (D = disk and B = broadcast) interaction means for aeschynomene seedling number at 10, 20, and 30 days after seeding in limpograss sods (1984).

| Seeding date | Day 10 Method | | Day 20 Method | | Day 30 Method | |
|---|---|---|---|---|---|---|
| | D | B | D | B | D | B |
| | seedlings $m^{-2}$ | | | | | |
| 1 Apr. | 23 a[†] | 8 b | 11 | 7 | 11 | 7 |
| 20 Apr. | 42 a | 8 b | 28 | 7 | 36 | 8 |
| 10 May | 5 a | 1 a | 67 | 42 | 49 | 25 |
| 20 June | 77 a | 81 a | 74 | 60 | 74 | 56 |
| SE[‡] | 2.9 | | 2.8 | | 2.8 | |
| F test[§] | **,**,* | | **,**,NS | | **,**,NS | |

†Method means within dates followed by the same letter are not significantly different (LSD, $P \leqslant 0.05$).
‡Standard error of an establishment method mean within a count date.
§Probability levels of $P \leqslant 0.01$ (**) and $P \leqslant 0.05$ (*) for method, date, and method x date interaction effects. NS = not significant.

Table A-3. Legume seeding date x seeding rate (kg $ha^{-1}$) interaction means for aeschynomene seedling number at 10, 20, and 30 days after seeding in limpograss sods (1984).

| Seeding date | Day 10 Rate 7 | Day 10 Rate 14 | Day 20 Rate 7 | Day 20 Rate 14 | Day 30 Rate 7 | Day 30 Rate 14 |
|---|---|---|---|---|---|---|
| | seedlings $m^{-2}$ | | | | | |
| 1 Apr. | 8 b† | 23 a | 6 a | 13 a | 7 a | 11 a |
| 20 Apr. | 14 b | 35 a | 12 b | 23 a | 17 b | 28 a |
| 10 May | 2 a | 4 a | 26 b | 82 a | 19 b | 55 a |
| 20 June | 31 b | 127 a | 24 b | 109 a | 24 b | 106 a |
| SE‡ | 2.9 | | 2.8 | | 2.8 | |
| F test§ | **,**,** | | **,**,** | | **,**,** | |

†Rate means within dates followed by the same letter are not significantly different (LSD, $P \leqslant 0.05$).
‡Standard error of a rate mean within a count date.
§Probability level of $P \leqslant 0.01$ (**) for rate, date, and rate x date interaction effects.

# LITERATURE CITED


Albrecht, K. A., and K. J. Boote. In Press. Photosynthetic recovery and regrowth of Aeschynomene americana and Hemarthria altissima swards after defoliation. Proc. XV Int. Grassl. Cong., Kyoto, Japan.

Albrecht, S. L., J. M. Bennett, and K. H. Quesenberry. 1981. Growth and nitrogen fixation of Aeschynomene under water stressed conditions. Plant and Soil. 60:309-315.

Allen, L. H., Jr. 1977. Soil water and root development. Soil & Crop Sci. Soc. Fla. Proc. 36:4-8.

Allen, N. O., and E. K. Allen. 1981. Leguminosae: A sourcebook of characteristics, uses and nodulation. U. W. Press, Madison, Wisconsin.

Bogdan, A. V. 1977. Tropical pasture and fodder plants. Longman, Inc., New York.

Boyd, F. T., and V. G. Perry. 1969. The effect of sting nematodes on establishment, yield, and growth of forage grasses on Florida sandy soils. Soil & Crop Sci. Soc. Fla. Proc. 29:288-300.

Burton, G. W. 1976. Legume nitrogen versus fertilizer nitrogen for warm-season grasses. PP. 55-72. In C. S. Hoveland (ed.) Biological N fixation in forage-livestock systems. Am. Soc. Agron., Madison, Wisconsin.

Carvalho, J. H. de. 1976. Plant age and its effect upon forage quality. M.S. Thesis, Univ. of Fla., Gainesville.

Chambliss, C. G. 1978. Bigalta limpograss. Fla. Coop. Ext. Serv. Agron. Facts #88. Univ. of Fla., Gainesville.

Chambliss, C. G. 1982. Aeschynomene. Fla. Coop. Ext. Serv. Agron. Facts #134. Univ. of Fla., Gainesville.

Christiansen, S. 1982. Energy reserves and agronomic characteristics of four limpograsses [Hemarthria altissima (Poir.) Stapf et C.E. Hubb.] for Florida's flatwoods. Ph.D. Dissertation, Univ. of Fla., Gainesville. Diss. Abstr. 44:377-B.

Christiansen, S., O. C. Ruelke, and R. O. Lynch. 1981. Regrowth in darkness as influenced by previous cutting treatment of four limpograss genotypes. Soil & Crop Sci. Soc. Fla. Proc. 40:156-159.

Cook, S. J. 1980. Establishing pasture species in existing swards: A review. Trop. Grassl. 14:181-187.

Cook, S. J. 1981. Establishment of pasture species oversown into speargrass pastures. CSIRO 1980-81 Annual Report, Trop. Crops & Pastures, pp. 98-101, Melbourne, Australia.

Cook, S. J., and K. F. Lowe. 1977. Establishment of siratro pastures. Trop. Grassl. 11:41-48.

Dantzman, C. L. 1978. Pasture fertilization practices for flatwood soils of South Florida. PP. 15-19. In Beef cattle and forage field day program. Ona ARC Res. Rep. RC-78-9, Univ. of Fla., Gainesville.

Euclides, V. P. B. 1985. Quality evaluation and cattle grazing behavior on bahiagrass and limpograss pastures. Ph.D. Dissertation, Univ. of Fla., Gainesville.

Fisher, M. J. 1973. Effect of times, height and frequency of defoliation on growth and development of Townsville stylo in pure ungrazed swards at Katherine, N. T. Aust. J. Exp. Agric. Anim. Husb. 13:389-397.

Freund, R. J., and R. C. Littell. 1981. SAS for linear models. SAS Institute, Inc., Cary, North Carolina.

Gallaher, R. N., C. O. Weldon, and J. G. Futral. 1975. An aluminum block digester for plant and soil analysis. Soil Sci. Soc. Amer. Proc. 39:803-806.

Gildersleeve, R. R. 1982. Agronomic evaluation of Aeschynomene species under mob grazing conditions. M.S. Thesis, Univ. of Fla., Gainesville.

Gillard, P. 1977. Establishment of Townsville stylo in native perennial grass pastures. Aust. J. Exp. Agric. Anim. Husb. 17:784-788.

Gomes, D. T. 1978. Establishment methods and comparative performance of five tropical legumes in grass sods. Ph.D. Dissertation, Univ. of Fla., Gainesville. Diss. Abstr. 39:5696-B.

Gomes, D. T., and A. E. Kretschmer, Jr. 1978. Effect of three temperature regimes on tropical legume seed germination. Soil & Crop Sci. Soc. Fla. Proc. 37:61-63.

Groya, F. L., and C. C. Sheaffer. 1981. Establishment of sod-seeded alfalfa at various levels of soil moisture and grass competition. Agron. J. 73:560-565.

Hambleton, L. G. 1977. Semiautomated method for simultaneous determination of phosphorus, calcium and crude protein in animal feeds. J. A. O. A. C. 60:845-852.

Hanna, W. W. 1973. Effect of seed treatment and planting depth on germination and seedling emergence in Aeschynomene americana L. Crop Sci. 13:123-124.

Hodges, E. M. 1977. Grazing summer annual legumes. PP. 5-11. In Beef cattle and forage field day program. Ona ARC Res. Rep. RC-1977-5, Univ. of Fla., Gainesville.

Hodges, E. M., A. E. Kretschmer, Jr., P. Mislevy, R. D. Roush, O. C. Ruelke, and G. H. Snyder. 1982. Production and utilization of the tropical legume aeschynomene. Fla. Agric. Exp. Stn. Circ. S-290. Univ. of Fla., Gainesville.

Hodges, E. M., and F. G. Martin. 1975. Forage production of perennial grasses as affected by fertilizer rate and season. Soil & Crop Sci. Soc. Fla. Proc. 34:158-161.

Hodges, E. M., and J. E. McCaleb. 1972. Aeschynomene in pasture programs. PP. 19-23. In Beef cattle and forage field day program. Ona ARC Res. Rep. RC-1972-2, Univ. of Fla., Gainesville.

Hodges, E. M., F. M. Peacock, H. L. Chapman, Jr., and R. E. L. Greene. 1974. Forage and supplement systems for beef cows in South-Central Florida. Soil & Crop Sci. Soc. Fla. Proc. 33:56-59.

Hodges, E. M., F. M. Peacock, H. L. Chapman, Jr., and F. G. Martin. 1976. Grazing trials with tropical grasses and legumes in peninsular Florida. Soil & Crop Sci. Soc. Fla. Proc. 35:84-86.

Hodgson, J. 1979. Nomenclature and definitions in grazing studies. Grass & Forage Sci. 34:11-18.

Humphreys, L. R. 1979. Tropical pasture seed production. 2nd ed. FAO, Rome.

Humphreys, L. R. 1980. Deficiencies of adaptation of pasture legumes. Trop. Grassl. 14:153-158.

Kalmbacher, R. S., and F. G. Martin. 1983. Light penetrating a bahiagrass canopy and its influence on establishing jointvetch. Agron. J. 75:465-468.

Kalmbacher, R. S., D. R. Minnick, and F. G. Martin. 1979. Destruction of sod-seeded legume seedlings by the snail (Polygyra cereolus). Agron. J. 71:365-368.

Kalmbacher, R. S., and P. Mislevy. 1978. Management of aeschynomene and hairy indigo for maximum yield and quality. PP. 11-14. In Beef cattle and forage field day program. Ona ARC Res. Rep. RC-1978-9, Univ. of Fla., Gainesville.

Kalmbacher, R. S., P. Mislevy, and F. G. Martin. 1978. Establishment of three legumes in bahiagrass sod using different herbicides and seeders. Soil & Crop Sci. Soc. Fla. Proc. 37:24-29.

Kalmbacher, R. S., P. Mislevy, and F. G. Martin. 1981. Minerals in the forage of American jointvetch and hairy indigo as affected by harvest height. Soil & Crop Sci. Soc. Fla. Proc. 40:124-127.

Kretschmer, A. E., Jr., and R. C. Bullock. 1980. Aeschynomene spp.: Distribution and potential use. Soil & Crop Sci. Soc. Fla. Proc. 39:145-152.

Kretschmer, A. E., Jr., and G. H. Snyder. 1979. Production and quality of limpograss for use in the subtropics. Agron. J. 71:37-41.

Kretschmer, A. E., Jr., and G. H. Snyder. 1981. Potential of Aeschynomene sp. for pastures in the tropics. Proc. XIV Int. Grassl. Cong., Lexington, Kentucky, pp. 783-786.

Kretschmer, A. E., Jr., R. M. Sonada, and G. H. Snyder. 1980. Resistance of Desmodium heterocarpon and other tropical legumes to root knot nematodes. Trop. Grassl. 14:115-120.

Loch, D. S., F. M. Hopkinson, and B. H. English. 1976. Seed production of Stylosanthes guyanensis. 2. The consequences of defoliation. Aust. J. Exp. Agric. Anim. Husb. 16:226-230.

Loch, D. S., and L. R. Humphreys. 1970. Effect of stage of defoliation on seed production and growth of Stylosanthes humilis. Aust. J. Exp. Agric. Anim. Husb. 10:577-581.

Mannatje, L. 't. 1978. Measuring quantity of grassland vegetation. PP. 63-95. In L. 't Mannatje (ed.) Measurement of grassland vegetation and animal production. Bull. 52. Commonwealth Bureau of Pastures and Field Crops, Commonwealth Agricultural Bureau, Farnham Royal, England.

McDowell, L. R., J. H. Conrad, and G. L. Ellis. 1983. Mineral deficiencies and imbalances and their diagnosis. Symposium on Herbivore Nutrition in Subtropics and Tropics--Problems and Prospects. April 1983, Pretoria, South Africa, 1-50.

McDowell, L. R., G. L. Ellis, and J. H. Conrad. 1984. Mineral supplementation for grazing cattle in tropical regions. Wld. Anim. Rev. 52:2-12.

McWilliam, J. R., and P. M. Dowling. 1970. Factors influencing the germination and establishment of pasture seed on the soil surface. Proc. XI Int. Grassl. Cong., Surfer's Paradise, Australia, pp. 578-583.

Middleton, C. H. 1970. Some effects of grass-legume sowing rates on tropical species establishment and production. Proc. XI Int. Grassl. Cong., Surfer's Paradise, Australia, pp. 119-123.

Milford, R., and D. J. Minson. 1965. Intake of tropical pasture species. Proc. IX Int. Grassl. Cong., Sao Paulo, Brazil, pp. 815-822.

Miller, I. L., and W. T. Williams. 1981. Tolerance of some legumes to six months of simulated waterlogging. Trop. Grassl. 15:39-43.

Minson, D. J. 1971. The nutritive value of tropical pastures. J. Aust. Inst. Agric. Sci. 37:255-263.

Minson, D. J. 1980. Nutritional differences between tropical and temperate pastures. PP. 143-157. In F. H. W. Morley (ed.) Grazing animals. Elsevier Scientific Publishing Company, Amsterdam, Holland.

Minson, D. J., and R. Milford. 1967. The voluntary intake and digestibility of diets containing different proportions of legume and mature pangola grass (*Digitaria decumbens*). Aust. J. Exp. Agric. Anim. Husb. 7:546-550.

Mislevy, P., R. S. Kalmbacher, and F. G. Martin. 1981. Cutting management of the tropical legume American jointvetch. Agron. J. 73:771-775.

Mitchell, C. C., Jr., and W. G. Blue. 1981. The sulfur status of Florida soils. 1. Sulfur distribution in spodosols, entisols, and ultisols. Soil & Crop Sci. Soc. Fla. Proc. 40:71-76.

Moore, J. E. 1980. Forage crops. PP. 61-94. In C. S. Hoveland (ed.) Crop quality, storage, and utilization. Am. Soc. Agron. & Crop Sci. Soc. Am., Madison, Wisconsin.

Moore, J. E., and G. O. Mott. 1973. Structural inhibitors of quality in tropical grasses. PP. 53-98. In A. G. Matches (ed.) Antiquality components of forages. Crop Sci. Soc. Am., Madison, Wisconsin.

Moore, J. E., and G. O. Mott. 1974. Recovery of residual organic matter from *in vitro* digestion of forages. J. Dairy Sci. 57:1258-1259.

Moore, J. E., L. E. Sollenberger, G. A. Morantes, and P. T. Beede. In Press. Canopy structure of Aeschynomene americana-Hemarthria altissima pastures and ingestive behavior of cattle. Proc. XV Int. Grassl. Cong., Kyoto, Japan.

Moore, J. E., M. A. Worrell, S. M. Abrams, W. R. Ocumpaugh, and G. O. Mott. 1981. Quality of tropical perennial grass hays. PP. 40-44. In Florida Beef Cattle Res. Rep., Univ. of Fla., Gainesville.

Moore, W. H. 1978. Managing jointvetch for deer and cattle. USDA For. Serv. Res. Note SE-259. S.E. For. Exp. Stn., Asheville, North Carolina, 6 pp.

Moore, W. H., and J. B. Hilmon. 1969. Jointvetch: Native legume in a new role for deer and cattle. USDA For. Serv. Res. Note SE-114. S.E. For. Exp. Stn., Asheville, North Carolina, 5 pp.

Moscardi, F. 1979. Effect of soybean crop phenology on development, leaf consumption, and oviposition of Anticarsia gemmatalis Hubner. Ph.D. Dissertation, Univ. of Fla., Gainesville. Diss. Abstr. 40:3571-B.

Mott, G. O. 1959. Symposium on forage evaluation. IV. Animal variation and measurement of forage quality. Agron. J. 51:223-225.

Mott, G. O., and J. E. Moore. 1970. Forage evaluation techniques in perspective. PP. L1-L10. In R. F. Barnes, D. C. Clanton, C. H. Gordon, T. J. Klopfenstein, and D. R. Waldo (eds.) Proc. Nat. Conf. Forage Quality Eval. and Util., Nebraska Center for Continuing Educ., Lincoln, Nebraska.

Norman, M. J. T., and R. Wetselaar. 1960. Losses of nitrogen on burning native pasture at Katherine, Northern Territory. J. Aust. Inst. Agric. Sci. 26:272-273.

Norris, K. H., R. F. Barnes, J. E. Moore, and J. S. Shenk. 1976. Predicting forage quality by infrared reflectance spectroscopy. J. Anim. Sci. 43:889-897.

Oakes, A. J. 1973. Hemarthria collection from South Africa. Turrialba. 23:37-40.

Oakes, A. J. 1978. Resistance in Hemarthria species to the yellow sugarcane aphid, Sipha flava (Forbes). Trop. Agric. 55:377-381.

Ocumpaugh, W. R. 1982. A new Hemarthria selected for persistence and quality. PP. 83-84. In Proc. 31st Annual Beef Cattle Short Course. An. Sci. Dept., IFAS, Univ. of Fla., Gainesville.

Ocumpaugh, W. R., and G. A. Dusi. 1981. Creep grazing for calves using warm-season forages. Forage & Grassl. Prog. 22:3-4.

Pasley, S. F. 1981. Screening for resistance to Meloidogyne incognita (KOFOID and WHITE) CHITWOOD in Aeschynomene and Desmodium species and herbicide effects on Aeschynomene americana L. Ph.D. Dissertation, Univ. of Fla., Gainesville. Diss. Abstr. 43:13-B.

Paul, W. R. C. 1951. Notes on legumes: 1. Ceylon Trop. Agric. 107:15-20.

Pitman, W. D., E. M. Hodges, and F. M. Peacock. 1984. Grazing evaluation of perennial grasses with yearling steers in peninsular Florida. J. Anim. Sci. 58:535-540.

Pitman, W. D., and R. S. Kalmbacher. 1983. Effect of length of fall grazing period on seed production of Aeschynomene americana. Fla. Acad. Sci. Abstr., pp. 1-2.

Quesenberry, K. H., L. S. Dunavin, Jr., E. M. Hodges, G. B. Killinger, A. E. Kretschmer, Jr., W. R. Ocumpaugh, R. D. Roush, O. C. Ruelke, S. C. Schank, D. C. Smith, G. H. Snyder, and R. L. Stanley. 1978. Redalta, Greenalta, and Bigalta limpograss, Hemarthria altissima, promising forages for Florida. Fla. Agric. Exp. Stn. Bull. 802, Univ. of Fla., Gainesville.

Quesenberry, K. H., and R. A. Dunn. 1978. Differential responses of Hemarthria genotypes to sting nematodes in a greenhouse screening trial. Soil & Crop Sci. Soc. Fla. Proc. 37:58-61.

Quesenberry, K. H., and W. R. Ocumpaugh. 1980. Crude protein, IVOMD, and yield of stockpiled limpograsses. Agron. J. 72:1021-1024.

Quesenberry, K. H., and W. R. Ocumpaugh. 1981. Forage potential of Aeschynomene species in North Central Florida. Soil & Crop Sci. Soc. Fla. Proc. 40:159-162.

Quesenberry, K. H., and W. R. Ocumpaugh. 1982. Mineral composition of autumn-winter stockpiled limpograsses. Trop. Agric. 59:283-286.

Quesenberry, K. H., W. R. Ocumpaugh, and O. C. Ruelke. 1981. Hemarthria altissima: A pasture grass for the tropics. Proc. XIV Int. Grassl. Cong., Lexington, Kentucky, pp. 788-791.

Quesenberry, K. H., W. R. Ocumpaugh, O. C. Ruelke, L. S. Dunavin, and P. Mislevy. 1984. Floralta--A limpograss selected for yield and persistence in pastures. Fla. Agric. Exp. Stn. Circ. S-312. Univ. of Fla., Gainesville.

Rhoades, H. L. 1980. Relative susceptibility of Togetes patula and Aeschynomene americana to plant nematodes in Florida. Nematropica. 10:116-120.

Robinson, G. S., and M. W. Cross. 1960. Improvement of some New Zealand grasslands by oversowing and overdrilling. Proc. VIII Int. Grassl. Cong., Univ. of Reading, England, pp. 402-405.

Rojas-Osechas, D. 1985. Mineral concentration of tropical grasses as affected by maturity, and effect of storage on forage organic components. M.S. Thesis, Univ. of Fla., Gainesville.

Ruelke, O. C., C. E. Dean, and Z. Z. Zakaria. 1974. Effects of scarification treatments on establishment of Aeschynomene americana L. Soil & Crop Sci. Soc. Fla. Proc. 34:114-116.

Ruelke, O. C., and K. H. Quesenberry. 1982. Limpograss for off-season forage production for beef cattle. PP. 39-42. In Florida Beef Cattle Res. Rep., Univ. of Fla., Gainesville.

Ruelke, O. C., and K. H. Quesenberry. 1983. Effects of fertilization timing on the yields, seasonal distribution and quality of limpograss forage. Soil & Crop Sci. Soc. Fla. Proc. 42:132-136.

Ruelke, O. C., K. H. Quesenberry, and W. R. Ocumpaugh. 1979. Planting technique effects on establishment, ground cover, production, and digestion of Hemarthria altissima (Poir.) Stapf et C.E. Hubb. Soil & Crop Sci. Soc. Fla. Proc. 38:40-42.

Ruelke, O. C., K. H. Quesenberry, and D. A. Sleper. 1976. Comparison of greenhouse vs. field plot techniques for evaluating new germplasm of limpograss, Hemarthria altissima (Poir.) Stapf et C.E. Hubb. Am. Soc. Agron. Abstr., p. 112.

Schank, S. C. 1972. Chromosome numbers in eleven new Hemarthria (limpograss) introductions. Crop. Sci. 12:550-551.

Schank, S. C., M. A. Klock, and J. E. Moore. 1973. Laboratory evaluation of quality in subtropical grasses: II. Genetic variation among Hemarthrias in In Vitro digestion and stem morphology. Agron. J. 65:256-258.

Sollenberger, L. E., K. H. Quesenberry, G. O. Mott, and J. E. Moore. 1985. Effects of grazing management on production and forage quality of a limpograss-jointvetch association. Proc. 1985 Forage and Grassl. Conf. Amer. Forage and Grassl. Council, Hershey, Pennsylvania, pp. 79-83.

Sollenberger, L. E., W. C. Templeton, Jr., and R. R. Hill, Jr. 1984. Orchardgrass and perennial ryegrass with applied nitrogen and in mixtures with legumes. 2. Component contributions to dry matter and nitrogen harvests. Grass & Forage Sci. 39:263-270.

Sonada, R. M., and J. M. Lenne. 1979. Diseases of Aeschynomene spp.: A bibliography. PP. 1-7. In Ft. Pierce ARC Res. Rep. RL-1979-11, Univ. of Fla., Gainesville.

Spicer, L., Jr., H. L. Chapman, J. E. Moore, and P. Mislevy. 1982. Mature aeschynomene haylage plus energy and protein for beef cattle. PP. 43-48. In Florida Beef Cattle Res. Rep., Univ. of Fla., Gainesville.

Steel, R. G. D., and J. H. Torrie. 1960. Principles and procedures of statistics. McGraw-Hill Book Co., Inc., New York.

Stockdale, C. R. 1984. Evaluation of techniques for estimating the yield of irrigated pastures intensively grazed by dairy cows. 1. Visual assessment. Aust. J. Agric. Anim. Husb. 24:300-304.

Tang, P. L., and O. C. Ruelke. 1976. Effects of management treatments on the reestablishment and persistence of Aeschynomene americana L. Soil & Crop Sci. Soc. Fla. Proc. 36:149-152.

Tergas, L. E., A. Ramirez, G. A. Urrea, S. Guzman, and C. Castilla. 1982. Potential animal production and management of pastures on ultisol soil in Colombia. Trop. Anim. Prod. 7:1-8.

Thornton, R. F., and D. J. Minson. 1973. The relationship between apparent retention time in the rumen, voluntary intake, and apparent digestibility of legume and grass diets in sheep. Aust. J. Agric. Res. 24:889-898.

Whitney, A. S., Y. Kanehiro, and G. D. Sherman. 1967. Nitrogen relationships of three tropical forage legumes in pure stands and in grass mixtures. Agron. J. 59:47-50.

Wiliapon, B., S. A. Gigir, and L. R. Humphreys. 1979. Apex, lamina and shoot removal effects on seed production and growth of Stylosanthes hamata cv. 'Verano'. Aust. J. Agric. Res. 30:293-306.

Wiliapon, B., and L. R. Humphreys. 1976. Grazing and mowing effects on the seed production of Stylosanthes hamata cv. 'Verano'. Trop. Grassl. 10:107-111.

Wilson, J. R., and D. J. Minson. 1980. Prospects for improving the digestibility and intake of tropical grasses. Trop. Grassl. 14:253-259.

# BIOGRAPHICAL SKETCH

Lynn E. Sollenberger was born on 20 June 1957, in Chambersburg, Pennsylvania. He is the son of Norman and Lois Sollenberger. With his two brothers and two sisters, he was reared on a dairy farm located five miles east of Chambersburg. Lynn graduated from Chambersburg Area Senior High School in 1975. He received a B.A. degree in biology from Messiah College (located near Harrisburg, Pennsylvania) in 1979.

From 1979 to 1981, Lynn worked in the area of temperate forage management with Dr. W. C. Templeton, Jr., at The Pennsylvania State University and the USDA Pasture Research Laboratory. He received his M.S. in agronomy from Penn State in August 1981.

For one year Lynn worked as a quality control analyst for Monsanto in Dayton, Ohio. Following a four-month stint as a research associate with Dr. Templeton at Penn State, he enrolled at the University of Florida in January 1983. Lynn is currently a candidate for the Doctor of Philosophy degree and is a member of the American Society of Agronomy, the American Forage and Grassland Council, the British Grassland Society, and the Crop Science Society of America. He is married to Andrea (Melachrinos) Sollenberger, and they have no children.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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Associate Professor of Agronomy

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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Assistant Professor of Agronomy

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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