PERSISTENCE OF SEVEN FORAGE LEGUMES UNDER THREE GRAZING REGIMES

By

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A degraded flatwoods pasture at Ona, Florida, was planted in 1986 with strips of Aeschynomene americana L., Alysicarpus vaginalis D.C., Vigna adenantha (G. F. Meyer) Marechal, Macherpa and Stainier, Desmodium heterocarpon (L.) D.C. cv. Florida, Galactia elliottii Nuttal., Macroptilium lathyroides (L.) Urb. and Desmanthus virgatus (L.), Willd. Late spring through summer (S/S) grazing, late spring through fall (S/S/F) grazing and ungrazed treatments were imposed during 1987 and 1988. Grazing pressure was 2.2 yearling heifers per ha in the summer, 1.2 yearling heifers per ha during the fall. Plant heights of the four upright-growing perennials were measured during 1987 and plant

population survival using May 1987 numbers as a base were taken during 1987, 1988 and 1989.

Height measurements indicated that D. virgatus, Galactia elliottii, Desmodium heterocarpon and Alysicarpus vaginalis in the two grazed treatments had reduced plant heights by June. Differentiation between all treatments was apparent in the last two species by mid-December.

Despite high persistence of A. vaginalis and Desmodium heterocarpon in May 1988, populations declined by May 1989. Desmanthus virgatus and Vigna adenantha had persistence values near 25% for the S/S treatment May 1989. Galactia elliottii, in May 1989, had the highest persistence of all entries with no differences between the grazed treatments.

A fall clipping trial indicated that Desmodium heterocarpon invested in seed production when not clipped. Desmanthus virgatus partitioned photosynthate to both herbage and roots while unclipped Galactia elliottii showed a marked increase in root mass and root non-structural carbohydrate but not effect on herbage production.

Aeschynomene americana, Macroptilium lathyroides and Desmanthus virgatus persistence mechanisms included unpalatable stem and seed production. Vigna adenantha survived through rapid regrowth, Galactia elliottii by storing nutrient reserves for early spring growth, while Alysicarpus vaginalis and Desmodium heterocarpon survived via prostrate growth and seed production.

CHAPTER ONE

INTRODUCTION

Grazing and browsing animals have had a large influence on the evolution of many plants from which they derive sustenance. Depending on grazing intensity and/or cycle as well as other environmental factors which affect herbage recovery, range and pasture plants have developed morphological or chemical factors which assist them in either deterring or surviving predation (Hodgkinson and Williams, 1983). Some species outgrow these terrestrial herbivores while others become inconspicuous via decumbent growth. A few have developed chemicals in the herbage which discourage ingestion via taste or anti-digestive factors. A third survival mode makes use of simple regenerative capacities in which plants acquire the ability to resprout and regrow faster than neighboring species after being damaged. In forage science it is this last group which primarily interests the pasture manager because these plants are acceptable to herbivores, nutritious and capable of permanence in the system.

It is natural, then, that these same adaptations in turn influence the acceptability of the plants as forage to herbivores. Depending on the feed amount and species available, harvesting animals will place differing pressures upon specific species within the area open to ranging. The rancher who plans to cultivate various legume and grass species to enhance domesticated animal productivity should therefore understand which species will be preferentially selected in forage mixtures and which will not benefit his/her program by being completely unacceptable to the animals.

In peninsular Florida very little of this information is available on tropical forage legumes. Pitman and Kretschmer (1984) have conducted initial work with a number of introduced legumes at the Ona Agricultural Research and Education Center (Ona AREC) encompassing 19 accessions from 17 species as well as 50 entries in a further work (Pitman et al., 1988). Grazing evaluation of single rows of these legumes was conducted in Paspalum notatum Flugge swards. Several species survived the grazing while others were completely eliminated. Of the survivors, only those for which seed was available could be studied further in this experiment. All those which did not survive, however, should not be excluded from further evaluation. The high degree of variability and complete lack of persistence of some legumes (for example Desmanthus virgatus (L.) Willd., which was utilized heavily by wildlife) cannot be attributed solely to climatic or edaphic factors in these studies since all plants were subjected to dense competition from grasses and little range in grazing management levels. Under less competition from grass or with more intense management, results might well have been different. For example, Pitman and Kretschmer (1984) reported very erratic establishment of Vigna adenantha (G.F. Meyer) Marechal, Mascherpa and Staineir and Vigna parkeri Bak. while under different management Pitman and Singer (1985) obtained good pasture coverage from the same species. The question yet to be answered, therefore, is not only will cattle graze or avoid species but what grazing management is needed to ensure proper establishment and maximum persistence while still maintaining high productivity.

Another aspect of tropical forage legumes which concerns ranchers in Florida is pasture fertilization needs. The purpose of the legume component in a grazing system is to provide improved mineral content, especially nitrogen in crude protein form. But must plant nutrients be added to native flatwoods soils to ensure proper establishment and persistence of these species? Producers, attempting to economize as much as possible in a financially-strapped cattle market, would prefer not to invest in fertilizer for native pastures. Information on which forage legume species might do well in unfertilized flatwoods pastures with native grasses is therefore of interest.

Frequently, researchers look at legume persistence in pastures by varying the stocking rate to which the species are subjected. Florida, however, with its distinct seasonal conditions where spring growth is often limited due to low rainfall, demands additional approaches. Summer growth in grasslands provides relatively abundant forage while fall deferment may be needed to allow annual legumes to set seed and perennial species to store energy for regrowth following winter frost. The period in which tropical forage legumes could be of greatest benefit to Florida ranchers is therefore the so-called "summer slump" of August and September. During these months herbage is abundant but low in quality, causing reduced animal weight gains or even loss despite excess forage (Pitman et al., 1984). One aspect of this study was therefore centered on evaluating selected legume species for potential to persist under grazing during the late spring forage quantity deficit and the summer forage quality slump.

This study sought to answer several questions pertinent to forage legumes in South-central Florida:

Objective 1. Of the species which have done well in initial introduction studies, determine which will persist under the various grazing regimes selected.

Objective 2. Among those that survive, discern what mechanisms are involved which allow species to tolerate the various grazing treatments under conditions found in Central Florida flatwoods.

Objective 3. Determine some of the relationships of defoliation to plant composition as these relate to regrowth in selected entries.

CHAPTER TWO

LITERATURE REVIEW

Plant Adaptations to Foraging

Plants may achieve persistence under grazing in various ways. Although climate, soils, pathogens and insect herbivory also affect plant survival mechanisms, animal herbivory has had an extensive effect on plant growth mechanisms such as reproductive cycles, regrowth characteristics or internal biochemical composition. In some more obvious strategies, plants may expand their populations under herbivory via basal regrowth, prostrate leaves and stems, well developed root nutrient storage, rhizome and stolon growth, rapid regeneration from various non-apical meristimatic tissue following trampling or defoliation, rapid seeding, seed dormancy, morphological and biochemical characteristics unfavorable to herbivore ingestion and digestion, and many other means (Hodgkinson and Williams, 1983).

Forage expansion via recruitment was reported by many researchers either through vegetative propagation or seeding. Vegetative propagation examples include *Medicago* sativa L. (Campbell, 1974) and Macroptilium atropurpureum (D.C.) Urb. (Hodgkinson and Williams, 1983). Jones and Evans (1977) reported on soil seed reserves which were high even in such perennials as Lotononis bainesii Baker, Desmodium intortum (Mill.) Urb. Thell. and Trifolium repens L. Taylor (1972) reported on several years' seed production by annual legumes and noted that different cultivars of the same species produced differing seed amounts under varying climatic conditions, greatly affecting seedling numbers the following years. Depending on previous seed crops and hardseededness, many species survive non-consecutive, poor seeding seasons according to Hagon (1974).

Regrowth Capacity

Individual plant regeneration after grazing also contributes to persistence in many species. If associations are grazed at a time when one component can regrow more rapidly than another yet both are grazed equally, then that species which recovers more quickly will likely exhibit greater dominance. In Florida, Pitman (personal communication) observed that many tropical legumes continued to grow further into the fall than did Paspalum notatum. The advantage which this C-4 grass possesses in superior growth rates is reduced perhaps due to decreased daylength or temperatures. In the spring, however, the roles are reversed when the P. notatum tends to start responding to warming trends faster than these legumes. Unlike the fall situation, this difference may be a result of more extensive fibrous root systems possessed by the grasses which give them an advantage in this moisture-scarce period. The normal legume advantage derived from deep taproots does not exist for many legumes in these spodosol pastures due to shallow hardpans in the soil.

Regrowth capacity is naturally more related to hereditary factors, especially when considered across a broad spectrum of environments. This is usually more important in perennials, for example Leucaena leucocephala (Lam.) de Wit (Hodgkinson and Williams, 1983) but can also be important in annuals or short lived perennials such as Stylosanthes humilis H.B.K. and Stylosanthes hamata (L.) Taub. (Gardner, 1981). Differing environments and grazing situations, of course, would greatly affect how well these adaptations would serve population survival.

Internal Composition

Plant biochemical factors which deter grazing before it even occurs are, at times, as important as recovery from grazing. Forage digestibility has been shown in many cases to influence passage rate and, therefore, acceptability to herbivores. This can be easily observed in such characteristics as coarse-stemmed morphologies implying high fiber contents as Donnelly and Hawkins (1959) saw in Lespedeza cuneata (Dumont) G. Don or as Hodges and McCaleb (1972) reported with Aeschynomene americana L. Often, however, these characteristics may be only a contributing factor or may even be masked by other anti-nutritional factors.

Other less superficially-apparent factors may involve tannin, which is thought to lower digestibility (Donnelly and Anthony, 1969 with Lespedeza cuneata), or such compounds as alkaloids which appeared to be toxic to cattle (Thomas et al., 1985). The alkaloid content can at times be such a factor that animals will not eat the legumes at all. Thomas et al. (1985) observed that in a mixed pasture of Andropogon gayanus Kunth and Zornia brasiliensis Vog. in Brazil, cattle grazed so selectively that the pasture was 100% legume after 3 yr. Not even during the dry season when the legume was the only green material available did cattle eat the high alkaloid-containing Zornia. There is some suspicion that the problem in this species may also be related to sulfur content (Lascano et al., 1981). Thomas et al. (1985) observed that Calopogonium mucunoides Desv. and Desmodium ovalifolium Walp. were also thought to have similar characteristics since, when planted in associations with grasses, they soon became the dominant component. Middleton and Mellor (1982) discovered that Calopogonium caeruleum

Hemsl., had similar characteristics. In a pasture with *Panicum maximum* Jacq this legume soon became the dominant species and average daily liveweight gain declined from 0.5 to 0.2 kg $head^{-1}$ over 2 yr.

Other plant biochemicals may actually attract herbivory. Crude protein may raise digestibility, for example with *Lespedeza cuneata* (Donnelly and Anthony, 1969). Sugars and soluble carbohydrates may also raise palatability (Cowlishaw and Alder, 1960) and thereby enhance selection. There are, however, many studies which indicate that these correlations do not hold or are at most confusing, a view Warmke et al. (1952) held after they found no significant correlation between soluble sugars and palatability in some tropical legumes.

Availability

Herbage availability of particular forages may be an important factor in forage selection. Reid (1951) stated that forage accessibility has considerable influence on utilization. Both Reid et al. (1967b) and Raymond and Spedding (1966) pointed out than increased intake of N-fertilized grasses may occur simply because these are more abundant that the unfertilized plants. The same may be true for P- and K-fertilized legumes. Bite size, the amount of herbage harvested with each bite, may be more important in these cases then palatability as Clark and Harris (1985) indicated in their study of white clover spatial distribution and its relationship to content in sheep grazing. Other studies, however, indicate no relationship between yield and grazing preference (for example Warmke et al., 1952).

Associated Species

If legume preference is the targeted information, the other legumes and associated grasses in which all are grown may influence cattle selectivity. Lascano et al. (1981), when comparing grazing selectivity of *Centrosema pubescens* Benth. in *Andropogon gayanus*, *Panimcum maximum* and *Brachiaria decumbens* Stapf. swards, determined that the legume was grazed more heavily as grass defoliation decreased *in vitro* digestibility, leaf/stem ratios and crude protein of the different grasses. Likewise, Carvalho et al. (1984) determined that *Neonotonia wightii* (R. Grah. ex Wightii and Arn.) was selectively grazed in *Panicum maximum*, *Paspalum notatum* and *Brachiaria mutica* Forsk. pastures only when grass components decreased considerably from grazing.

Not only cattle selectivity but associated grass growth habit may affect legume persistence. When compared to pure grass or pure legume swards, legume components of grass-legume mixtures are more likely to be inferior (Crowder and

Chheda, 1982). Tall bunch grasses may shade out some legumes while allowing others to thrive in the open ground between tufts. Dense mat-forming grasses, in contrast, may choke out some low-growing legume species yet allow other viney types greater productivity due to structural support which allows more access to sunlight. In either of these cases, cattle access may also be affected by associated grass morphology (Strange, 1960). Although Strange (1960) in Kenya found that there was simply no substitute for general adaptability to the local environmental conditions, twining legumes did better with taller, erect grasses while more prostrate legumes were inferred to do best with lower growing grasses.

Growth Habit

Perhaps the most important factor in forage persistence under grazing is growth habit. Canopy structure, whether composed of one species or an association, heavily influences what and how much a grazing animal can collect as Moore et al. (1985) showed with Aeschynomene americana and Hemarthria altissima (Poir.) Stapf and C.E. Hubb in Florida. These authors concluded that as herbage concentration increased in the upper canopy, intake per bite of those species present also increased.

Twining legumes, in particular, have difficulties tolerating direct grazing and trampling. Thomas et al. (1985) pointed out that some Galactia and Centrosema species have stems and buds which are very vulnerable to this pressure and therefore do not persist well in directly grazed pastures. Those climbing species which can root at the nodes, however, may overcome this limitation as do Centrosema macrocarpum Benth., Centrosema pubescens (Thomas et al., 1985) and Vigna parkeri (Cook and Jones, 1987).

Another morphological type which has difficulties under direct and heavy grazing is the group containing upright growing species with a limited capacity for regrowth from non-apical meristimatic tissue (Thomas, 1986). Annuals especially figure heavily in this group. Once grazed close to the ground, these often are unable to recover sufficiently to set seed, especially if harvested late in the growing season. Thomas et al. (1985) and Thomas (1986) also included in this group species of the genera Stylosanthes and Centrosema.

In a study of 50 legume accessions, Pitman et al. (1988) concluded that prostrate species such as a perennial Alysicarpus vaginalis (L.) D.C., Vigna parkeri and Desmodium barbatum Benth. had better persistence under heavy grazing than under lighter grazing pressure. They also pointed out that light grazing produced the opposite effect in some of these low-growing types.

There is often a trade-off of yield for persistence when decumbent varieties are compared to erect ones. Leach et al. (1982) found that in terms of numbers, spreading Medicago sativa types were more persistent. In actual dry matter production, however, the erect lines were higher despite lower numbers of individuals.

An aspect which few research trials address is the length of time different legumes take to establish and the indication this might give of subsequent persistence. It appears that those legumes, especially perennials, which take longer to establish, are often more persistent due to deeper, more developed root systems. Wong and Eng (1983) grazed recently established pastures at 3.8 cattle ha^{-1} over 3 yr and found that quickly establishing perennials such as Stylosanthes guianensis (Aubl) Sw. cv. Cook did not maintain vigor and ground cover as did more slow to establish Desmodium ovalifolium (L.) Benth. A prime example of the slow to establish legumes, one adapted to well drained soils, is Arachis glabrata Benth. According to Prine et al. (1986) and Prine et al. (1981), germplasm of this legume is well suited to droughty sands but should not be grazed at all the season of establishment after being planted from rhizomes. Even faster establishing annuals such as Aeschynomene americana L. (Kalmbacher et al., 1988) or short-lived perennials like Macroptilium lathyroides (L.) Urb. (Pitman et al., 1986) should not be grazed after seedlings enter the upper canopy. Heavy grazing just prior to this stage to avoid closed canopies and grass competition does benefit the stands, however. Once well established, grazing may commence.

Kretschmer (1988) mentioned two other factors which assisted some legumes in overcoming temporary, if not necessarily continuous, over-grazing. The first is simply woodiness. Unpalatable stem will naturally discourage total destruction of some species such as *Leucaena* spp. The other is the capacity to store energy and resprout via crowns or rhizomes. The main factor involved may be that these anatomical structures are unavailable to the animal for consumption as in the case of some *Arachis* spp.

Effects of Direct Grazing on Legume Production

Many studies have gathered information on the above-ground effects of grazing on legumes. The most obvious and most often documented, of course, is the abundance of leaf and stem. Davidson and Brown (1985) working with *Neonotonia wightii* and *Desmodium intortum* described but one example in which excessive grazing pressure decreased green matter while moderate stocking rates maintained or increased the proportion of legume in the pasture.

Fewer studies, however, have documented the actual numbers of plants that survive differing grazing regimes. Gardner (1981) working with Stylosanthes hamata indicated that this species survived normal defoliation pressures via weak perennation but resorted to soil seed reserves when mature plants were destroyed by overgrazing. That author found that only 0.03% of all seedlings survived to a third growing season. Jones et al. (1980) discovered in a study of grazed Macroptilium atropurpureum lines that plant numbers declined differently for various lines as the pasture matured. Increasing the stocking rate from 2 to 3 steers ha^{-1} resulted in plant densities of 5.3 and 1.9 plants m^{-2}, respectively, in 5 yr. Jones (1979), working with the same species and a range of grazing treatments, however, found that grazing frequency at differing stocking rates had no effect on plant density and seedling regeneration.

Roberts (1980) reviewed several publications reporting the effect of botanical composition on animal gain due to differing stocking rates. His general conclusions were that botanical composition in some pastures is not affected by increased stocking rates which do, however, result in decreased liveweight gain per head after a certain level. Higher stocking rates on other pastures did result in distinctive botanical composition changes but, surprisingly, did not affect animal gain. This later finding would indicate that the pastures resulting from poor management were as good or better than the original mixture.

Very few studies, however, have concentrated on determining what happens beneath the soil surface to grazed and over-grazed plants. Even fewer studies have focused on the effect of differing grazing regimes on root carbohydrates. For information on this area the literature is limited to studies on clipped plants. Trejos and Borel (1985), for example, studied the effect of different cutting heights and intervals on total non-structural carbohydrates of Stylosanthes capitata Vog. No differences were found, even in root and base content although percent and not total carbohydrate was reported. They did note, however, that the longer the plant rested after cutting, the greater the percent carbohydrate recovery in the roots and bases. They felt that they should shorten the recovery periods (27 d was the shortest) to discern differences between treatments and species.

Whiteman and Lulham (1970) studied the effect of defoliation, both mechanical and animal, on nodule number and weight. They found that in Macroptilium atropurpureum mean weight per nodule was reduced whereas in Desmodium uncinatum (Jacq.) D.C. grazing and cutting reduced nodule number rather than size.

Methods for Measuring Plant Acceptability

The amount of forage which is removed during grazing is termed herbage utilization (Heady, 1964). Preference, then, can be measured in the relative utilization of the various forages compared if availability is equal among species. As Cook and Stoddart (1953) pointed out in the case of rangelands, plant utilization (and by deduction preference) is most commonly measured by using length or weight of the grazed versus the ungrazed pasture portions. Reid et al. (1967a) in their work with temperate grasses used a palatability index calculated as the proportional dry matter consumption from each treatment compared to that consumed in all treatments combined.

Marten (1970) warned against not taking growth during grazing into account when calculating utilization. Heady (1964) used grazing exclosures to ensure this difference did not affect the accuracy of the results obtained in his work.

Previous Studies in Tropical Forage Legume Persistence

Most studies in forage legume persistence have involved plant survival under various grazing pressures and/or frequencies rather than grazing periods as was studied in this dissertation. These studies, however, hold some pertinent information which can be utilized here.

Common Grazing

Although simply planting various legumes side by side in a pasture and allowing cattle continuous, unlimited access to them is a rather simple study method, it encompasses several possible draw-backs. Foremost among these is the danger of assuming that any plots with superior persistence have the best species, cultivars or accessions. The survival may simply be due to lower acceptance by the animals. More palatable legumes may provide higher animal weight gains in more appropriately managed situations when compared to persistent but unpalatable lines.

It may be useful, therefore, to plant an ungrazed control next to the grazed plots to determine whether disappearance, if it occurs, is due to animal preference or genetic limitations on the part of the plant. Even then, however, too much competition from ungrazed grass or no pressure from direct grazing and trampling can give misleading or at least incomplete information.

Pitman and Kretschmer (1984) studied seventeen tropical legumes under common grazing at one grazing pressure and frequency in Florida with measurable results. After the third year growth and second year grazing from May to November, only four species showed any significant survival. In terms of original planted area, Macroptilium lathyroides covered 9% and Vigna luteola (Jacq) Benth. 6% of the pasture, a non-significant difference from the other 13 species. Aeschynomene americana covered 28% and Vigna parkeri topped the list at 42% cover, both significantly higher than the others but also different from each other. Most species were lost due to low vigor and failure to regenerate. According to the authors, at least one, (Macroptilium atropurpureum), succumbed to its incapacity to tolerate direct grazing, while others disappeared at least in part due to selective grazing (e.g. Desmathus virgatus). The main reason for failures in persistence according to the authors, however, was the heavy competition from the associated Papalum notatum as well as the pressures of direct grazing.

Pitman et al. (1986) also used common grazing pastures to compare nine Stylosanthes guianensis var. guianensis accessions, three Stylosanthes hamata and Stylosanthes humilis accessions along with Aeschynomene americana in peninsular Florida. Grazing pressure varied from 2 animals ha^{-1} during June and July the first year on two replications to 3 animals ha^{-1} on all four replications the second year to no animals the third year. Proportion of original cover surviving at the end of the trial was highest for Aeschynomene americana at 80% with the next closest being two different accessions of Stylosanthes guianensis at 10%.

The last two were not significantly different from the rest of the legumes which had no measurable survival.

Difficulties in this type of evaluation, especially its repeatability in dissimilar edaphic and climatic zones, is exemplified in the 1985 Pitman et al. publication which covered four different sites in Florida and Costa Rica. Thirty-six legumes were studied (although not all at every place) under grazing. The authors did not claim to have identical grazing pressures at all four sites since this would be virtually impossible. Perhaps because of this and the variation in edaphic and climatic conditions, the results varied considerably from site to site.

The above-mentioned report exemplifies the great variability which exists in the tropical and sub-tropical areas when dealing with forage adaptability. A cautious approach to this research area would entail initial observations such as Pitman et al. (1985) did for each new climatic or ecotypic zone followed by more specific work to be done on the three or four species which show the most promise in distinct environments.

Frequency of Defoliation

General forage management wisdom indicates that legumes are far less able to survive repeated defoliation than are grasses (Kretschmer, 1988). Smith (1970), working with sheep and Medicago sativa in Australia, for example, showed that persistence was much higher at both high and low stocking rates when rotational grazing was utilized, thereby limiting defoliation frequency. He also found that the more paddocks were subdivided in the rotations, the higher the productivity. Unfortunately, the economics of such highly-divided pastures may be rather prohibitive in some conditions. Leach et al. (1982) used a flexible grazing frequency approach to study different M. sativa lines in Australia. Their study compared lines of different morphologies under a system in which plots were grazed to the ground and then allowed to recover for 6 wk. Over a period of 3 yr, persistence was better for spreading lines than for erect ones although actual winter production was higher for the locally developed erect cultivar 'Hunter River.'

Lazier (1981) used an unusual grazing regime in which a 6-wk interval between grazing was the only set factor. At grazing time cow-calf pairs were allowed to graze plots of native Belizean Calopogonium caeruleum, Desmodium canum (Gmel) Schinz and Thell and Desmodium gyroides (D.C.) Hask. to an unspecified but even degree. Desmodium gyroides, although it had a 34% mortality over the 3-yr period, proved to have the highest grazing index (derived by multiplying amount grazed by degree grazed) and the greatest dry matter availability after the trial.

Whiteman (1969) in Australia also used an unusual variation on the frequency theme in Chloris gayana Kunth pastures planted to Macroptilium atropurpureum, Lotononis bainesii, Glycine javanica L. and Desmodium uncinatum. For 2 yr, plots were grazed to a 6- to 10-cm stubble height by sheep. What was unusual was that the intervals between grazing were determined by seasonal, genetic and animal directed capacities of the plots to recover. This turned out to be approximately 6 wk during the warm season and 9 wk in the cooler periods. The author did not state what criterion was used to determine full recovery and regrowth. Under this regime, Glycine appeared to have persisted best while Lotononis exhibited the lowest survival and productivity.

Jones and Clements (1987) studied various introductions and lines of Centrosema virginianum (L.) Benth. as well as Macroptilium atropurpureum cv. Siratro, Desmodium intortum cv. Greenleaf, Centrosema pubescens cv. Belalto and Vigna parkeri cv. Shaw under 3-wk rest, 4-d graze regimes. For 4 yr only 1.5 animals ha^{-1} were used but the last 4 yr the 4-d grazing was extended on half the experiment to produce a 2.3 animals ha^{-1} stocking rate. Results varied for different species under different conditions but after 8 yr at the low pressure, only the Centrosema virginianum lines still comprised significant portions of the pasture with the highest line totaling 18% cover. All the other plots, with the exception of Macroptilium atropurpureum, were persistent during the first 5 yr at this level although differences did exist. At the high stocking rate nothing persisted after 4 yr.

Jones (1979), examined not only different grazing pressures but different grazing frequencies as well. In his study, M. atropurpureum pastures were rested for 3, 6 and 9 wk between 4-d grazing regimes at stocking rates ranging from 0.8 to 2.8 head ha^{-1}. He found that the 3-wk rest was inadequate and legume yield declined dramatically. He further noted that although decline at the higher stocking rates was greater than at the lower rates, the longer rest period allowed much more effective recovery at all stocking rates.

Less-frequent grazing, however, did not always result in higher legume percentage in pasture studies. This was especially true when low frequencies were combined with low grazing pressure, as Santillan (1983) found in Ecuadorian pasture mixes including Neonotonia wightii, Centrosema pubescens, Panicum maximum and Pennisetum purpureum Schumach. In these low-use situations the erect growing grasses outcompeted the viney legumes and shaded them out. Maraschin (1975) found the same general rule to be applicable in a Florida study utilizing both viney and erect legumes (Macroptilium atropurpureum and Desmodium intortum) in a more decumbent type grass (Cynodon dactylon (L.) Pers.

cv. Coastcross-1). A balance avoiding over-use and under-use, therefore, seems to work best when grazing frequency can be varied in a management situation.

Defoliation Intensity

Most legumes have shown a decline in persistence with an increase in stocking rate (Cowan et al., 1975). Humphreys (1980) and Jones (1979) both indicated that viney legumes were especially susceptible to an increase in grazing pressure. Bryan and Evan (1973) agreed with this general observation but added that trailing legumes encountered difficulties not only under heavy but under moderate stocking rates as well.

Of course, there is a limit to which even the hardier species can withstand excessive grazing. Smith (1970), working with Medicago sativa in a subtropical setting with sheep, found that 2.0 wethers ha^{-1} was the ideal stocking rate in a continuous system but plants still survived even at 4 animals ha^{-1}. When he used 4.9 wethers ha^{-1} in a six paddock rotational system, however, there were plant losses from "digging."

There are some species which appear to thrive under heavier grazing. Normally these are varieties with a prostrate morphology which benefit from the removal of upright growing competition (Bryan and Evan, 1973). Native or naturalized legumes that have adapted to local heavy grazing especially seem to fit into this category. Partridge (1980) studied a locally prevalent Desmodium heterophyllum (Willd.) D.C. in Fiji and discovered that it persisted better and contributed more to cattle feed at stocking rates over 3 head ha^{-1} where introduced species like Macroptilium atropurpureum disappeared.

Sometimes, however, simply fostering better seedling establishment, especially in the case of annuals, early in the establishment of the pasture greatly increases establishment and persistence rates. Stobbs (1969), for example, found that Stylosanthes gracilis H.B.K. did better as stocking rates increased from 1.65 to 5.0 head ha^{-1}. Shaw (1978), working with the same genus but another species, Stylosanthes humilis, found the same general rule to be true and related the phenomenon directly to reduced competition from native grasses early in establishment.

In another angle on the grass competition problem, Hutchinson (1970), working with sheep and Trifolium repens in a subtropical setting, found that the legumes did poorly not only under heavy stocking rates but under light pressure as well due to heavy competition from grasses. A medium rate seemed most effective in maintaining persistence.

Davidson and Brown (1985) conducted a grazing study in which a pasture of Panicum maximum, Neonotonia wightii and Desmodium intortum was deliberately overgrazed until the legume component was only 3%. Pasture rest, reduced stocking rate (1 head ha^{-1}) and reduced stocking rate plus phosphate fertilization all resulted in legume recovery to over 50% of the dry matter component after 2 yr. A third treatment in which the original heavy stocking rate was maintained (2 head ha^{-1}) showed no recovery over a 2-yr period. Milk yield and weight change of the grazing animals were positively correlated with the status of the legumes in the respective plots.

Other researchers have found that stocking rates do not seem to influence persistence in some species. Rika et al. (1981) varied stocking rates between 2.7 and 6.3 animals ha^{-1} with various legume-grass mixtures and concluded that pasture botanical composition was not related to grazing pressure.

Santillan (1983) found that grazing durations varying from 1 to 28 d on a pasture of Centrosema pubescens, Neonotonia wightii, Panicum maximum and Pennisetum purpureum likewise had little effect on legume persistence. Unlike the above study, however, this researcher found that grazing pressures of 1.6, 3.3, 5.0, 6.6, and 8.3 kg dry matter on offer/100 kg body weight and rest periods between grazing of 0, 14, 28, 42, and 56 d did have a significant effect. Especially at combinations of high grazing pressures and short rest periods the legume percentages tended to decrease in this relatively high rainfall Central American region.

Alcantara and Abramides (1984) tested five legumes in grass mixtures and also found that the legumes that did well at low intensity grazing thrived at high levels as well. In their case Macroptilium atropurpureum and Neonotonia wightii seemed most adapted to the particular Brazilian situation studied. Not surprisingly, Cunha et al. (1984), in the same region found that the same species with the addition of Centrosema pubescens did equally well at low, medium and high grazing intensities utilizing a seasonally adjusted grazing system. Wilson et al. (1982) did a wide survey of Aeschynomene falcata (Poir) D.C. in the Australian subtropics and discovered that it also fit into this omni-surviving group. Whether under light periodic grazing or continuous heavy pressure (kept to 5 cm year round) this species survived and actually spread in all cases except one waterlogged site. This would indicate that there are some species so well adapted to the local conditions and direct grazing that overgrazing to the point of destroying stands may be difficult. The studies did not state, however, whether animal gain on these persistent legumes was higher than on other less tolerant species.

Where grazing sensitive species are used, the resultant decline in animal output per area should not be surprising. Watson and Whiteman (1981) subjected Centrosema pubescens, Macroptilium atropurpureum and Sylosanthes guianensis cv. Endeavor mixtures in various grasses to 1.8, 2.7, 3.6 and

4.5 animals ha^{-1} over 4 yr. In the pasture with the most productive grass species, live-weight gain per ha per yr showed a definite quadratic relation ranging from just under 400 kg at the low pressure to 600 kg at 3.6 animals ha^{-1} and then back down to 500 kg at the highest stocking rate. Less productive grasses did not show this relationship as distinctly. The relationship between animal gain and percent legume component was also quadratic for all mixtures.

Put-and-take Management

Some researchers have bypassed the stocking rate dilemma by using a variation of continuous grazing in which numbers of cattle theoretically are maintained at the optimum stocking rate such that the legume component had a good chance to persist. Under these conditions species' survival or lack thereof should result from genetic traits rather than management.

Buller et al. (1970) implemented this system in Brazil to study Sylosanthes gracilis, and Glycine javanica in association with Digitaria decumbens (Stent). Year round grazing resulted in Sylosanthes gracilis disappearance and Glycine javanica persistence despite good animal acceptance of both legumes. This might indicate that even at carefully set stocking rates, those species which continue to grow year round (even in the dry season as does Sstylosanthes gracilis) will likely suffer more losses than those which are dormant part of the year as was Glycine javanica in this study. Production of rhizomes, stolons or rooting nodes in trailing legumes, although not documented in this case, might also give viney species advantages over those which are completely dependent on seed production for reproduction. This should be especially true in continuously grazed systems.

Hodges et al. (1976) studied two annual legumes in Florida, Aeschynomene americana and Indegofera hirsuta L., under a put-and-take system with several different grass associations. These authors found that productivity of the two legumes varied widely year to year but that Aeschynomene americana had a higher potential pasture yield. Both species were found to be equally productive in animal weight gain per area when compared to nitrogen fertilized grass-only pastures when at least 25% legume cover was obtained (Hodges et al., 1977).

In a variation of the put-and-take management system, Thomas (1976) subjected paddocks of Desmodium uncinatum, Macroptilium atropurpureum, Desmodium intortum, Macroptyloma axillare (E. Mey.) Verdc., Neonotonia wightii, and Stylosanthes guianensis cvs. Schofield and Endeavor to grazing by Malawian fat-tailed sheep to a constant 10-cm height. The results showed a markedly higher persistence and productivity by Desmodium uncinatum and Macroptyloma axillare. The two Stylosanthes cultivars were the most productive the first year but were out-produced by the others in subsequent years.

Thomas and Andrade (1984) repeated this general evaluation scheme using cattle on Brazilian savannah. In this study only the genus Stylosanthes was studied, using eight accessions of Stylosanthes guianensis, Stylosanthes macrocephala Ferr. and Costa and Stylosanthes capitata. What is noteworthy in this study is that different species of the same genus and different varieties of the same species responded to grazing in markedly different ways. In their particular situation Stylosanthes macrocephala CIAT 1582 and both Stylosanthes capitata CIAT 1019 and 1097 outproduced the other species and entries after 4 yr grazing to a constant 10-cm height. In a later trial, Thomas and Andrade (1986) again found differences within species (Stylosanthes spp. and Zornia spp.) under both equal and different grazing pressures.

Pitman et al. (1988) also utilized a put-and-take system to study 50 legume accessions planted in common pastures. The authors studied persistence under a heavy stocking rate defined as 4 to 6 head ha^{-1} and a light rate ranging from 1 to 3 head ha^{-1}. Perhaps due to a combination of various other factors including heavy grass competition at establishment, intermittent winter frosts and summer flooding, the results showed there were no outstanding legumes among those studied. Of those that did survive after 3 yr, Macroptilium atropurpurem had higher persistence (3.5 %) under the low stocking rate when compared to the high rate. Desmodium barbatum was the opposite, exhibiting minimal but higher persistence (1.5 %) under the high as compared to the low stocking rate.

Deferred Grazing

Davidson and Brown (1985), in a previously mentioned experiment with dairy cattle on Panicum maximum, Neonotonia wightii and Desmodium intortum pastures, showed that deferred grazing at critical times sometimes could result in overall legume yield increases reflected in higher milk production over the year and decreased weed problems. By allowing no grazing during the spring season, critical winter yields were higher than in those treatments under continuous use. Jones (1979) likewise found that in pastures of Macroptilium atropurpureum where productivity, but not plant density, had declined from overgrazing (excessive frequency and stocking rate), prolonged rests were very effective in pasture regeneration. In this study an entire growing season was allowed for recovery prior to use again in the autumn. It was noted, however, that pastures in already reasonable condition recovered far more effectively than those in overgrazed treatments.

Gutteridge (1985b) allowed Stylosanthes spp. and Macroptilium atropurpureum pastures under a 2.5 to 6.5 animal units ha^{-1} stocking range to rest during the dry season not so much for management purposes but to imitate indigenous grazing systems in Thailand. Four-day grazing periods and 16-d rests were also used. Although this experiment unfortunately did not have a year-round grazed control, the author found that the effects of different stocking rates were far less distinct after than before each rest period. Gutteridge (1985a) found that Macroptilium atropurpureum was the only entry which showed strong perennation although it, like all the Stylosanthes entries, tended to spread or survive (mostly at lower stocking rates) more via seeds than vegetatively. The author surmised that the seed dependent entries had greater difficulty surviving under the deferred grazing of the dry season because they did not have the water extracting root capacity of the Macroptilium atropurpureum pastures. It would appear, then, that for shallow-rooted annuals or perennials which act as annuals in some conditions to benefit from deferment that rest should occur during late growing seasons when moisture is still available to those roots.

Annuals particularly seem to benefit from intensive grazing during some periods and no grazing in others.

Stockwell (1984a) found this to be true in Australia with Centrosema pascuorum Martimus ex. Benth. cv. Bundey. His recommendations included heavy grazing during the early rainy season to limit grass growth and limited grazing from late wet to early dry season to allow seed set. The same author (Stockwell, 1984b) from work with another annual legume, C. pascuorum cv. Cavalcade, recommended slightly different management for a species to be used primarily during the dry season. Heavy early grazing to keep grasses under control during establishment was still recommended but thereafter use of the pasture was to be deferred until the dry season when it was most critically needed.

Sollenberger et al. (1987a) studied the effect of early season deferment on the annual legume Aeschynomene americana in Hemarthria altissima cv. Floralta pastures. These researchers found that grazing the grass early in the spring until the legume seedlings had reached at least the two-leaf stage and then withholding grazing until they were at least 60 cm tall gave the highest dry matter production. The authors pointed out, however, that when grazing was initiated in the 20- to 40-cm height cattle seemed to be able to utilize the more uniform and less lignified plants more efficiently. This was illustrated by decreased stem quality indicators (digestibility and nitrogen content) and leaf/stem ratio as grazing initiation was delayed (Sollenberger et al., 1987b).

In contrast to annuals, most perennials establish more effectively with deferred grazing during the early stages. Andrews and Comudom (1979) found that subjecting legumes such as *Desmodium intortum* and *Trifolium repens* to light pressure gave far better establishment. They found that the perennial, *Stylosanthes guianensis*, in particular suffered if grazed heavily during early establishment. The recommendation to graze annuals heavily is more likely to assist establishment where faster-growing sod grasses are stronger and less so where pure legume stands or bunch grasses are present.

CHAPTER THREE

METHODS AND MATERIALS

Field Study

The site for the experiment was a deteriorated 2-ha pasture at the Ona Agricultural Research and Education Center (Ona AREC). Vegetative cover within the pasture was highly variable. Portions contained primarily native range vegetation including such grass species as low panicums (*Panicum spp*.), creeping bluestem (*Schizachyrium stoloniferum* Nash.), and broomsedge bluestem (*Andropogon virginicus* L.), while others were dominated by vasey grass (*Paspalum urvillei* Steud.) and common bermudagrass (*Cynodon dactylon* (L.) Pers.).

The soil was Immokalee fine sand (sandy, siliceous, hyperthermic Arenic Haplaquod) with a composite pH of 5.6, and nutrient elements at the following levels (mg kg^{-1}): phosphorus 4.1, calcium 655, potassium 8, copper 0.54, iron 10.3, magnesium 203, manganese 1.0 and zinc 1.1.

The pasture was chopped in the fall of 1986 with a Marden rolling chopper and sprayed in April 1987 with 2-4-D (2, 4-dichlorophenoxyacetic acid, butoxyethyl ester) selective herbicide to control broadleaf weeds in the pasture. Individual blocks were rotovated to a 30-cm depth in May 1986 and planting took place throughout the June, July and August period.

Experimental Layout

The overall experimental design was a randomized complete block design with six blocks. Treatments were arranged in a strip-plot as described by Gomez and Gomez (1984). Legume entries were assigned as north-south strips. East-west strips were made up of the three grazing treatments of ungrazed, grazed from May through December and grazed only during late spring and summer (fall deferment). Common grazing was used for the entire experiment with cattle excluded from the grazing treatments at the appropriate seasons.

Legume main plots (north-south strips) measured 7.0 by 15.0 m consisting of five plant rows each with 84 individual plants spaced 30 cm apart. Each row was separated by 1.0 m and an additional 2.0 m was inserted between plots. Grazing treatments (east-west) measured 5.0 by 49.0 m. Each grazing treatment was separated from the others when appropriate by a five-strand barbed-wire fence.

The legumes evaluated were: Aeschynomene americana L., Alysicarpus vaginalis D.C., Desmanthus virgatus (L.), Willd., Desmodium heterocarpon (L.) D.C. cv. Florida, Galactia elliottii Nuttal., Macroptilium lathyroides (L.) Urb. and Vigna adenantha (G. F. Meyer) Marechal, Mascherpa, and Stainier.

Annuals and short-lived perennials, for which unlimited seed was available, Aeschynomene americana and Macroptilium lathyroides, were broadcast throughout the individual plots on 13 April 1987. Seeding rate was 10 kg ha^{-1}, 5 kg ha^{-1} of which was unhulled seed for the Aeschynomene americana. For all other species except Desmodium heterocarpon, seed was limited. These were therefore initially planted during the summer months of 1986 in peat cups or directly transplanted from native stands to 30-cm spacings. All peat cups were inoculated with "cowpea" type Rhizobium at seeding to avoid a disadvantage in nodule formation compared to transplanted native species.

Heavy rains in May followed by a dry period in June forced replanting of many individual plants in 1986. Those seeded directly were especially affected by waterlogging in early summer. Aeschynonome americana and Macroptilium lathyroides suffered complete establishment failure. These were therefore reseeded in April, 1987 at the original rates after light discing of the specific plots.

Any plants which died from among the other species were replaced during 1986 up through August. Due to unavailability of seed, Galactia elliottii plots were not completely filled in with plants in peat cups. The G. elliottii plots were subsequently completed in the fall by transplanting plants from a nearby range site.

Deer (Odocoileus virginianus seminolus Goldman and Kellogg) and rabbit (Sylvilagus spp.) consumption of the legumes, especially Aeschynomene americana, Macroptilium lathyroides and Desmanthus virgatus, was a problem. Rabbit fencing was placed around the latter plots but no effort was made to exclude deer. Instead, a large area of Macroptilium lathyroides and Aeschynomene americana was planted in a neighboring pasture to divert the deer in the summer of 1987.

Grazing Management

On 22 May 1987 eight crossbred yearling heifers were placed in the pasture. On 28 May, 4 head (2.2 head ha^{-1} remaining) of these were removed after the initial excessive herbage growth had been reduced. On 15 September animal numbers were reduced to 2 head (1.2 head ha^{-1}) on the s/s/f treatment strips due to forage reduction. These last 2 head were taken off the pasture on 1 December when cold and frost effectively stopped forage regrowth.

Cattle were excluded from the zero graze treatments by a permanent five-strand barbed-wire fence. Cattle were left on the pasture in a continuous grazing system, but were excluded from the spring/summer-only grazing strips on 15 September 1987 by barbed-wire fences.

In 1988, the wire around the fall-deferment strip was removed and two yearling steers were added to the pasture in May. The wire was put up once again on 15 September 1988 and cattle removed on 1 December.

Persistence Evaluation

Established plant populations were determined on 21 May 1987 by counting surviving plants before cattle were added to the study on 22 May 1987. The numbers gathered in each subplot at this date were then used in computing persistence percent at subsequent dates.

Plant numbers were taken on December 1987, May 1988, December 1988, and May 1989. Persistence was calculated as plant counts on specific date / plant count of May 1987 * 100. This allowed for determination of a population change after May 1987. An increase in population would register as over 100% persistence.

In subsequent months of 1987, heights of individual plants of the center rows in each subplot were determined. This was discontinued during the winter months when little or no growth occurred.

During the 1988 growing season, species numbers were determined only in May and December. In May 1989 the final count was taken on the inside three rows.

Statistical Analysis

The statistical analysis included an analysis of variance (AOV) of percent persistence as well as average plant heights recorded within species at different grazing pressures.

Since annuals and perennials had distinctive growth, seeding and regrowth habits, these were analyzed in separate groups. Only the perennials, with the exception of the viney Vigna adenantha, were measured for effect of grazing on individual plant heights during 1987. The annuals were not sufficiently established for data collection at this time.

Pot Study

A pot study to observe species physiological responses to varying defoliation stresses was conducted. In order to parallel the field trial, this experiment was conducted during late fall, winter and early spring of 1987-1988. The entries were subjected to clipping stress just prior to the normal dormant period. By observing the regrowth potential and biochemical composition of the plants during and after clipping, it was hoped that factors might be found to explain field trial results. Regeneration after the short cold days of January, February and March was also observed to determine the effect pre-winter clipping stress had on post-winter regrowth.

Species were selected based on their initial field establishment success and seed availability. Of those that showed promise, three were selected for their upright or climbing growth habits, conducive to height-related clipping regimes. The species employed were *Desmanthus virgatus*, *Galactia elliottii*, and *Desmodium heterocarpon*.

Germinated seeds of these species were placed in peat cups and seedlings were allowed to establish. Plants of uniform size were then inoculated with cowpea inoculum and transplanted into a pot containing 1 kg of unfertilized Immokalee fine sand (sandy, silicious, hyperthermic Arenic Haplaquod). Soil used was taken from the field trial pasture and consisted of the top 20 cm sifted through a 1-cm screen. No amendments were added and the plants were watered from above whenever necessary to keep the soil moist throughout. All pots were allowed an adaptation period of 6 wk during which any dead or weak seedlings were replaced. The experiment was conducted on tables with opaque fiberglass roofing for protection from direct precipitation.

The experimental design was a randomized complete block with four replications. Three clipping treatments were imposed during the autumn period. These will be referred to as 'autumn clipping treatments.' The autumn clipping treatments were imposed every 2 wk for periods of 0, 6, and 12 wk beginning on 15 October 1987. Thus, treatments consisted of an unclipped control, three clippings during the initial 6 wk (early clipping), and six clippings over a 12 wk period (extended clipping). Initial clipping heights in the early and extended clipping treatments were set at 50% of the blocks' average height for each species using the tallest or longest point as reference. Subsequent clippings were made at that same height. At each clipping, material was separated by leaf, stem and reproductive organs, dried at 72°C for 48 h, weighed and composited with other clippings from that same pot. Each experimental unit consisted of 16 pots.

During 8 to 13 January 1988, plants in half of the pots in each experimental unit were sacrificed. Herbage in these pots was clipped at a 3-cm height above the soil surface, separated into leaf, stem and flowers/pods, dried, weighed and composited with previous clippings where appropriate. The remaining plant portions, consisting of roots and stem bases, were washed free of soil, dried at 72°C for 48 h and prepared for total non-structural carbohydrate (TNC) analysis.

Of the remaining eight pots per experimental unit, a strip plot arrangement of treatments was imposed with four pots in each experimental unit harvested to a 3-cm height during 8 to 13 January 1988. This was done to represent the normal above-ground herbage destruction which occurred in the field due to frosts and freezes. The four remaining pots in each experimental unit were not subjected to a winter harvest. After 16 wk (May 1988) all plants were harvested to a 3-cm stubble height. Both fractions, above-ground herbage and roots, were recovered, dried, and weighed.

Herbage from the autumn clipping treatments and the winter harvest from four pots within each experimental unit was composited and ground through a Wiley mill equipped with a 1-mm screen to provide sufficient material to analyze crude protein. Roots were likewise weighed, ground and composited except that only roots of two pots were used per sample for TNC analysis. Above-ground herbage from the spring harvest was treated in the same manner except that material from only two pots was composited to form a laboratory wet chemistry sample. See Table 1 for a breakdown on experimental unit subsamples.

Nitrogen content was determined by an auto-analyzer method employing a modified aluminum block digestion procedure described by Gallaher et al. (1975). Sample

Table 1. Number of subsamples per experimental unit in the pot study.

Treatment	Variable	Subsample number
Autumn clipping	Herbage mass	16
Winter harvest	Herbage mass	12
Winter harvest	Herbage nitrogen	3
Winter harvest	Root mass	8
Winter harvest	Root total non-structural carbohydrate	4
Spring harvest	Herbage mass	4
Spring harvest	Root mass	4
Spring harvest	Herbage nitrogen	2

weight was 0.25 g, catalyst used was 3.2 g of 9:1 K_2SO_4:$CuSO_4$ and 2 ml H_2O_2. Ammonia in the digestate was determined by semiautomated colorimetry (Hambleton, 1977).

Roots from the winter harvest were analyzed for TNC following a modified enzymatic extraction procedure adapted from Smith (1981). Reducing sugars were analyzed with Nelson's (1944) colorimetric approach to the copper reduction method first described by Somogyi (1945).

CHAPTER FOUR

RESULTS

Field Study

Height of Perennials, 1987

Inter-species height differences were not compared since species morphologies differed and responses of individual species to grazing were the primary interest. Of the perennials in this study, *Desmanthus virgatus* was the only upright species, *Alysicarpus vaginalis* and *Desmodium heterocarpon* were normally prostrate while *Galactia elliottii* displayed upright growth in early stages and a viney habit latter in maturity. *Vigna adenantha* displayed essentially only viney growth.

Analysis of intra-species height differences are shown by date for the 1987 grazing season in Table 2. No differences (*P*=0.36) existed between grazing treatments for any species before cattle were added on 22 May.

After 38 grazing days (30 June) there was a distinct difference (*P*=0.01) between the zero grazing and the two

Table 2. Plant height means of Alysicarpus vaginalis (AV), Desmodium heterocarpon (DH), Galactia elliottii (GE) and Desmanthus virgatus (DV) under zero (Z), spring/summer (S/S) and spring/summer/fall (S/S/F) grazing treatments during the 1987 growing season.

Date	Grazing treatment	AV	DH	DV	GE
		cm			
21 May	Z	10.2a†	15.6a	23.3a	16.3a
	S/S	10.9a	16.7a	22.6a	19.1a
	S/S/F	11.7a	16.2a	21.5a	20.4a
30 June	Z	13.2a	18.7a	24.3a	20.9a
	S/S	10.3b	12.3b	18.8b	12.3b
	S/S/F	9.6b	11.0b	16.9b	12.6b
29 July	Z	20.1a	24.5a	29.1a	25.3a
	S/S	9.6b	11.0b	18.4b	13.4b
	S/S/F	10.7b	12.2b	17.2b	10.8b
1 Sept	Z	24.3a	27.9a	31.5a	25.8a
	S/S	11.1b	10.5c	16.4b	12.9b
	S/S/F	11.0b	13.4b	14.6b	10.9b
1 Oct	Z	26.3a	31.2a	31.5a	23.8a
	S/S	13.6b	10.6c	18.6b	11.9b
	S/S/F	10.1c	13.5b	15.1b	11.1b
3 Nov	Z	29.0a	28.4a	30.7a	19.4a
	S/S	17.2b	11.4b	19.3b	11.5b
	S/S/F	10.1c	10.5b	14.6c	14.8ab
15 Dec	Z	27.2a	27.5a	28.3a	19.9a
	S/S	16.6b	12.1b	18.5b	15.3ab
	S/S/F	9.0c	9.1c	14.5b	9.3b

†Means at each date within columns differ ($P<0.05$) if not followed by a common letter according to Duncan's Multiple Range Test.

grazed treatments for all four species measured. This difference persisted throughout the grazing season except in the case of Galactia elliottii on 15 December ($P=0.14$).

During September ($P=0.0002$) and October ($P=0.0006$) an unexplained difference between the spring/summer (s/s) and spring/summer/fall (s/s/f) grazing treatments in Desmodium heterocarpon appeared. By November, due perhaps to differing grazing treatment, this unexplained difference disappeared.

The removal of grazing animals on 15 September from the fall-deferred treatment produced differences ($P=0.005$) within 15 d between the s/s and s/s/f treatments in Alysicarpus vaginalis. This difference became more and more pronounced as fall progressed (Fig. 1).

Fall deferment from grazing of Desmodium heterocarpon took a little longer to affect plant heights but became apparent by December ($P=0.0001$). This delayed effect of deferment may have been in part due to the unexplained differences between the s/s and s/s/f treatments which existed prior to animal removal (Fig. 2). Within two months after grazing deferment the relative order in height between the s/s grazing treatment and the s/s/f grazing treatment had been reversed.

Desmanthus virgatus height reacted in much the same manner as Desmodium heterocarpon except that at the December

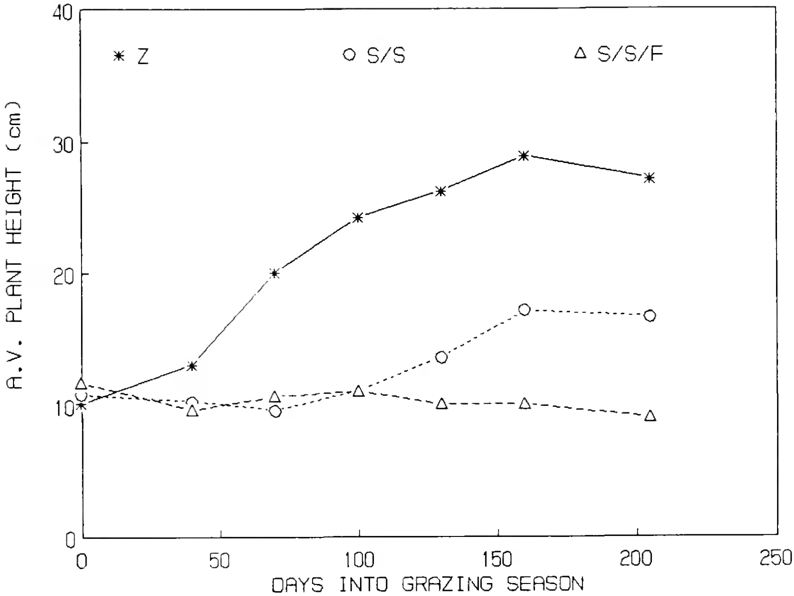

Fig. 1. Effect of zero (Z), spring/summer (S/S) and spring/summer/fall (S/S/F) grazing on height of <u>Alysicarpus vaginalis</u> (A.V.) beginning 20 May 1987 with cattle added day 0 and taken off S/S day 115.

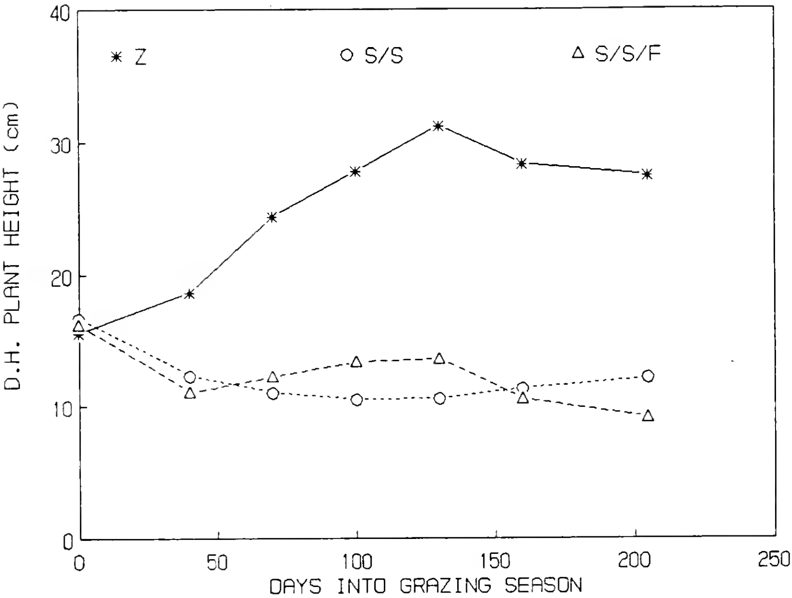

Fig. 2. Effect of zero (Z), spring/summer (S/S) and spring/summer/fall (S/S/F) grazing on height of Desmodium heterocarpon (D.H.) beginning 20 May 1987 with cattle added on day 0 and excluded from S/S on day 115.

reading the differences (*P*=0.0007) apparent between s/s and s/s/f which appeared in November (Fig. 3) became statistically non-significant. This was perhaps due to heavy deer predation since the cattle-excluding fences were not a deterrent for these browsing animals. It was not due to senescence since plants in these plots continued to generate new growth until killed back by frost.

Galactia elliottii, despite an unexplained increase in s/s/f plant height in November, showed perhaps the most interesting trend by December. Although there was no difference (*P*=0.14) between the s/s and the s/s/f treatments, there also was no difference between the s/s and zero grazed plots. This indicated that *G. elliottii* either benefited sufficiently from the fall rest to catch up with the zero treatment or the zero treatment senesced sooner due to fewer recently produced leaves. It was noted to shed well over 50% of its leaves in the range during the cold months. This became apparent when the 33% height increase for s/s was compared with only 3% increase for the zero graze treatment during the 40-d period in which neither was grazed (see also Fig. 4 and the near-steady height decrease throughout the fall period illustrated by the decline in the zero graze line from day 100 on).

Height measurements indicated, at least in the second growing year and first grazing season, that these four

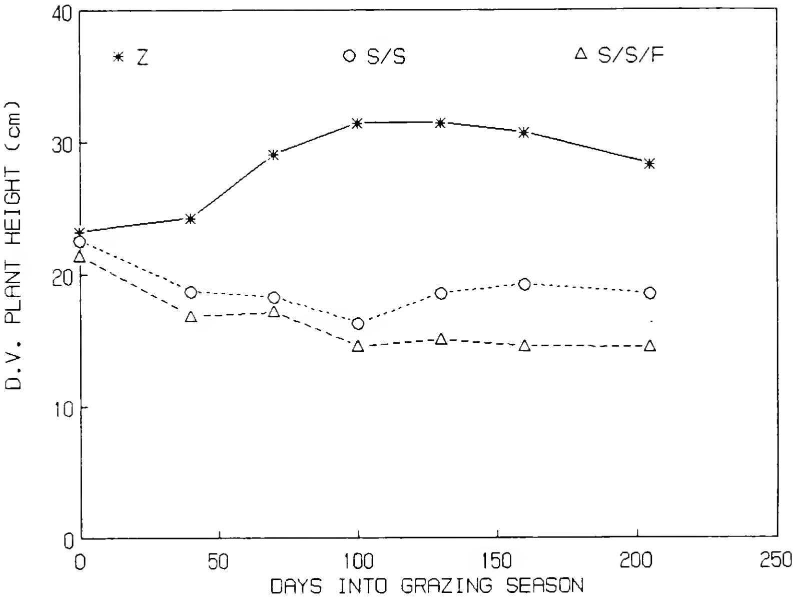

Fig. 3. Effect of zero (Z), spring/summer (S/S) and spring/summer/fall (S/S/F) grazing on height of <u>Desmanthus virgatus</u> (D.V.) beginning 20 May 1987 with cattle added day 0 and excluded from S/S day 115.

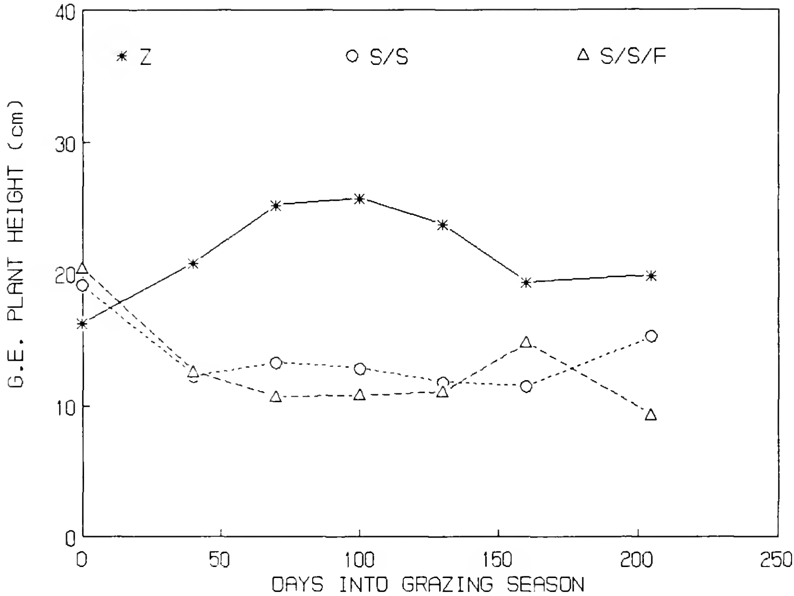

Fig. 4. Effect of zero (Z), spring/summer (S/S) and spring/summer/fall (S/S/F) grazing on height of <u>Galactia elliottii</u> (G.E.) beginning 20 May 1987 with cattle added day 0 and excluded from S/S day 115.

forage legumes were grazed by the yearling heifers. Figures 1 through 4 illustrate graphically, however, that plant herbage growth did respond to fall deferment from grazing except in the case of Desmanthus virgatus. In this entry, heights followed this general trend but the s/s and s/s/f means were not different (P=0.14) from each other. All others, particularly the more decumbent Alysicarpus vaginalis, showed a positive response to the pre-winter rest by addition of new foliage.

In Fig. 5, plant heights of both s/s and s/s/f treatments as a percent of the ungrazed treatment are shown for all perennials measured in December (Table 3). Alysicarpus vaginalis suffered the least in the s/s treatment (P=0.11), recovering to 70% of the zero treatment height. Desmanthus virgatus at 66% was not different from either Alysicarpus vaginalis or Desmodium heterocarpon. This last species, which registered 53%, was not statistically different from the most shortened entry, Galactia elliottii at 49%.

Figure 5 also illustrates the uniform grazing defoliation which occurred among most perennial species in the s/s/f grazing (P=0.47). Only Desmanthus virgatus, at 50%, differed from the others which ranged between 34 and 36% of the ungrazed treatment. Woody stem development early in establishment of D. virgatus may have limited the degree of defoliation of this upright growing legume.

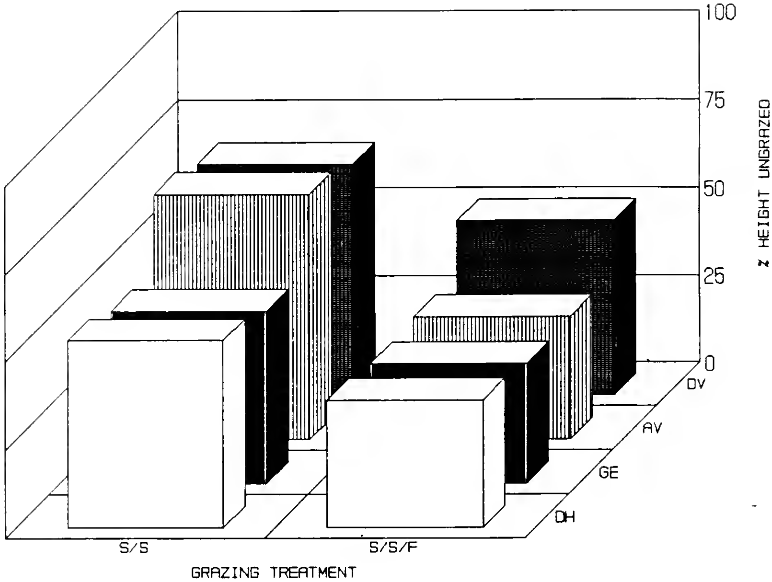

Fig. 5. Mean percent height remaining in spring/summer (S/S) and spring/summer/fall (S/S/F) grazed plots of <u>Alysicarpus vaginalis</u> (A.V.), <u>Desmodium heterocarpon</u> (D.H.), <u>Desmanthus virgatus</u> (D.V.) and <u>Galactia elliottii</u> (G.E.) compared to ungrazed plots on December 1987.

Table 3. Height of _Alysicarpus vaginalis_ (AV), _Desmodium heterocarpon_ (DH), _Galactia elliottii_ (GE) and _Desmanthus virgatus_ (DV) under spring/summer (S/S) and spring/summer/fall (S/S/F) grazing treatments in December 1987 as a percent of ungrazed plots.

Grazing regime	AV		DH		DV		GE	
	%							
Z	100a†	A §	100a	A	100a	A	100a	A
S/S	70a	B	53bc	B	66ab	B	49c	B
S/S/F	35b	C	36b	C	50a	C	34b	B

†Means within lines differ (_P_<0.05) if not followed by a common lower case letter according to Duncan's Multiple Range Test.

§Means within columns differ (_P_<0.05) if not followed by a common upper case letter according to Duncan's Multiple Range Test.

Persistence Within Perennials, 1987-1989

Since the interactions between species and grazing treatment existed for all dates ($P<0.001$), the discussion of persistence of both within and among perennials, as well as within and among the annually reseeding group will be limited to the simple effects.

After one grazing season, *Alysicarpus vaginalis* appeared to have suffered few losses under grazing and increased substantially where protected completely or in the fall (Table 4). There was an apparent difference ($P=0.09$) between s/s/f and zero grazing, however. The increase to 214% in the zero grazing treatment, (Fig. 6), was thought to be at least in part due to artificially low plant counts at the base date in 1987. This species was noted to regrow slowly from frosted plants early in the growing season.

Winter stress affected population dynamics considerably in this species. By May 1988, the zero graze treatment was lower ($P=0.09$) than the s/s treatment as seen in Fig. 6. This may have been due to *A. vaginalis*'s failure to either store sufficient nutrients in roots when forced to compete with ungrazed grasses or due to an enhanced susceptibility to frost and freeze when forced to grow upright in heavy competition.

By the end of the second grazing season, December 1988, the same basic trends held except that the s/s plots had

Table 4. Mean percent survival comparison within and among perennials Alysicarpus vaginalis (AV), Desmodium heterocarpon (DH), Galactia elliottii (GE), Desmanthus virgatus (DV), and Vigna adenantha (VA) under zero (Z), spring/summer (S/S) and spring/summer/fall (S/S/F) grazing treatments using May 1987 as a base date.

Date	Grazing treatment	AV		DH		DV		GE		VA	
		%									
Dec 1987	Z	214a[†]	A[§]	86a	B	68a	BC	38a	C	101a	B
	S/S	153ab	A	85a	B	71a	B	47a	B	53b	B
	S/S/F	93b	A	95a	A	54a	B	12b	C	13c	C
May 1988	Z	47b	B	88a	A	55a	B	86a	A	110a	A
	S/S	109a	A	91a	AB	36b	D	51b	CD	71b	BC
	S/S/F	89ab	A	98a	A	25b	C	51b	B	20c	C
Dec 1988	Z	57b	B	66a	B	62a	B	32a	C	109a	A
	S/S	155a	A	61a	B	25b	B	20b	B	42b	B
	S/S/F	75b	A	55a	B	10b	C	4c	C	5c	C
May 1989	Z	2a	C	10a	C	47a	B	136a	A	63a	B
	S/S	12a	B	12a	B	26ab	B	52b	A	24b	B
	S/S/F	8a	B	18a	B	9b	B	55b	A	1c	B

†Means within columns at each date differ ($P<0.05$) if not followed by a common lower case letter according to Duncan's Multiple Range Test.

§Means within lines at each date differ ($P<0.05$) if not followed by a common upper case letter according to Duncan's Multiple Range Test.

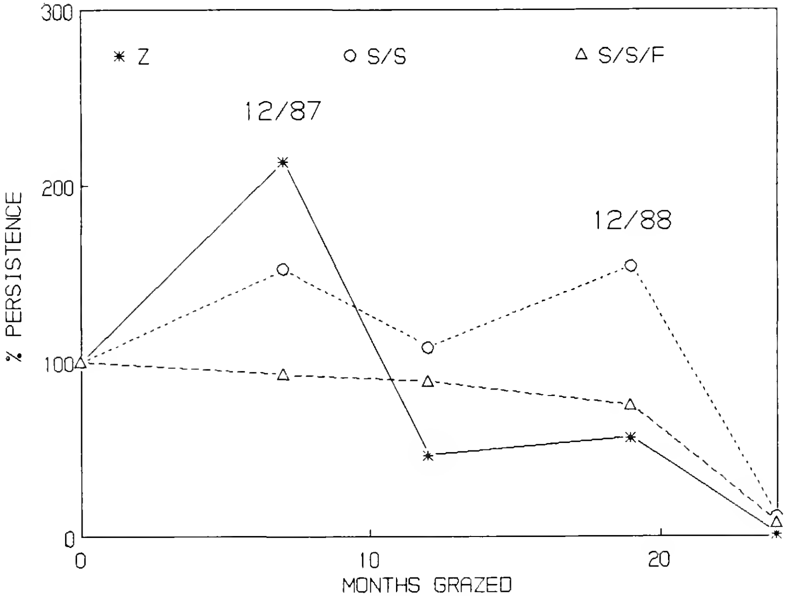

Fig. 6. Mean percent persistence of Alysicarpus vaginalis starting 22 May 1987 under zero (Z), spring/summer (S/S) and spring/summer/fall (S/S/F) grazing treatments.

higher persistence than the s/s/f treatment. During the winter of 1988-1989 there was a late frost on 26 February followed by an unseasonably dry spring with only 38% of the normal rainfall at Ona AREC. This latter climatic stress more than any may have caused the dramatic decline in A. vaginalis plant population throughout the experiment. Both regenerating plants and new seedlings were destroyed. As a result, this species was essentially eliminated so that the differences between treatments seen earlier no longer held (P=0.46).

Desmodium heterocarpon, on the other hand, showed less effect (P>0.65 for all dates) of grazing regime on individual plant survival (Table 4). This held true throughout the experiment as can be seen in the lack of differentiation between treatments in Fig. 7. It, along with Alysicarpus vaginalis, seems to have suffered the most from the late winter frost and early spring drought of 1989.

Desmanthus virgatus showed a similar lack of response (P=0.33) to grazing at the end of 1987 (Table 4). Following both the winter die-back and another grazing season, however, the differences between the two grazed treatments and the ungrazed treatment became more apparent (P=0.004) as illustrated in Fig. 8. During the two readings in 1988 the s/s and s/s/f treatments were not different (P>0.05) although there was a trend for greater survival in the s/s treatment.

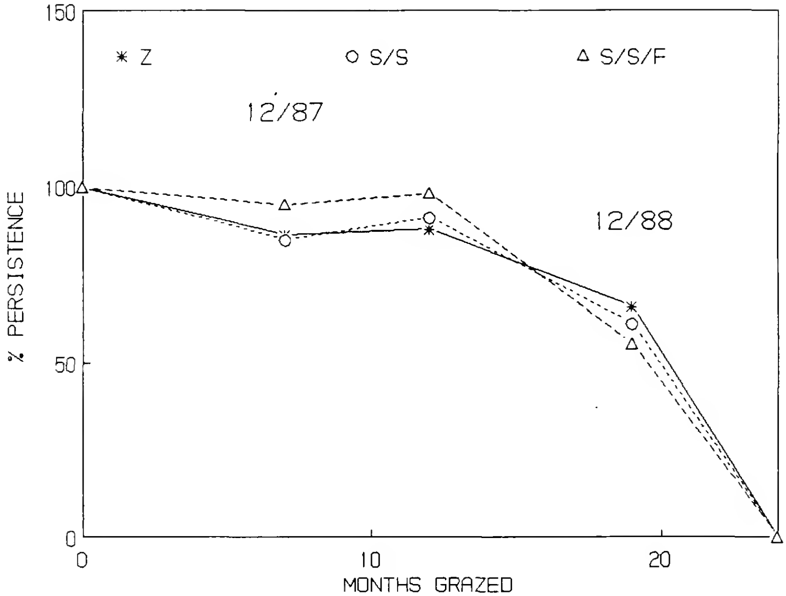

Fig. 7. Mean percent persistence of <u>Desmodium heterocarpon</u> starting 22 May 1987 under zero (Z), spring/summer (S/S) and spring/summer/fall (S/S/F) grazing treatments.

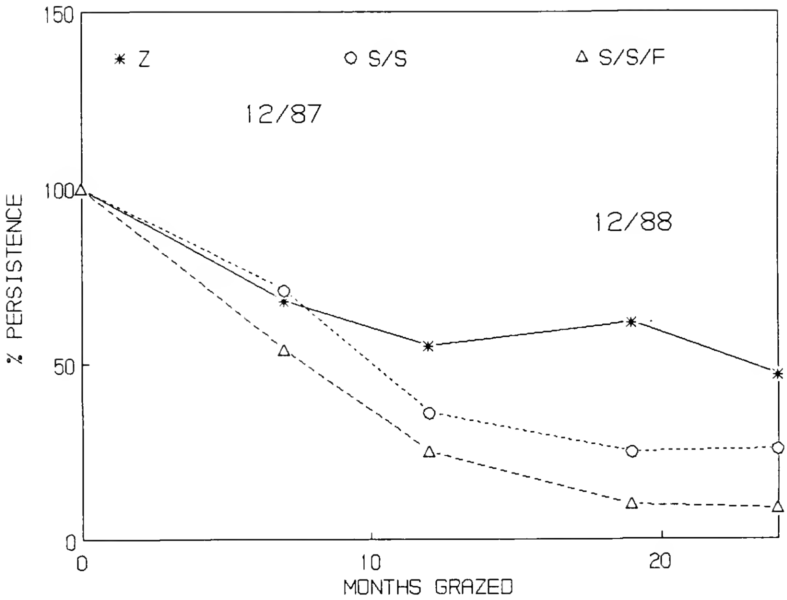

Fig. 8. Mean percent persistence of <u>Desmanthus virgatus</u> starting 22 May 1987 under zero (Z), spring/summer (S/S) and spring/summer/fall (S/S/F) grazing treatments.

After the stressful winter and early spring of 1989, *Desmanthus virgatus* continued to show a treatment effect (*P*=0.01). The notable exception was a lack of difference (*P*>0.05) between the s/s and the ungrazed treatments. Perhaps due to condition improvement from fall rest, plants in the s/s grazing regime were able to maintain their vigor as well as the plants in the ungrazed treatments.

There was a noticeable response (*P*=0.01) to fall grazing by *Galactia elliottii* at the end of 1987 (Table 4 and Fig. 9). Although plant survival was not high for the zero and s/s treatments at this time, the 12% survival for the s/s/f plots was especially low. No differences (*P*>0.05) existed between the zero and s/s treatments at this time indicating a response on the part of this native legume to fall deferment from grazing in the first year.

Winter stress showed some interesting results for this species. In May 1988, many individual plants which were not visible in December resprouted. This resulted in a 126% increase at the zero graze level, a 9% increase with the fall deferred treatment and a 325% increase for the s/s/f treatment. No seedlings were observed. These results indicate that the early spring growth of this species (earlier than most grasses) might substitute for fall deferment. Differences (*P*=0.03) between grazing treatments still existed.

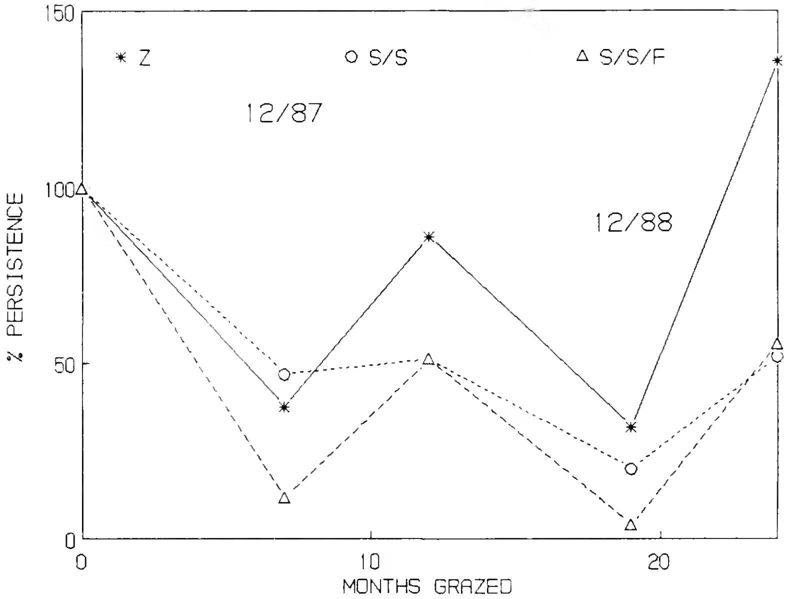

Fig. 9. Mean percent persistence of <u>Galactia</u> <u>elliottii</u> starting 22 May 1987 under zero (Z), spring/summer (S/S) and spring/summer/fall (S/S/F) grazing treatments.

By the end of a second grazing season, 1988, both grazed plots were inferior to the ungrazed treatment. The s/s, however, was more persistent (P=0.004) than the s/s/f, indicating, again, a benefit from fall deferment. This benefit did not allow the numbers to maintain the 50% recovery measured at the end of 1987.

Despite the harsh winter and early spring of 1989, *G. elliottii* showed the same recovery after the cold months as it did in 1988. As happened a year before, the difference that existed between the two grazing treatment populations before winter disappeared in the spring although differences between these and the control were still apparent (P=0.001). In fact, all three groups showed an increase in numbers over a year previous with the ungrazed population propagating itself to 36% over the original plant number in May 1987.

Vigna adenantha showed the most consistent response to fall deferment, showing higher persistence than the s/s/f treatment and lower than the ungrazed control for all dates (P=0.001 for all dates). At every date measured except May 1989 (Table 4), the zero treatment also showed over 100% persistence, completely covering each plot and invading adjacent borders. This species also showed that during the cold months it could regenerate from completely denuded tops. During the 1987-88 winter, the s/s treatment especially showed improvement with an increase of 34% (illustrated in Fig. 10). As in the case of *Galactia*

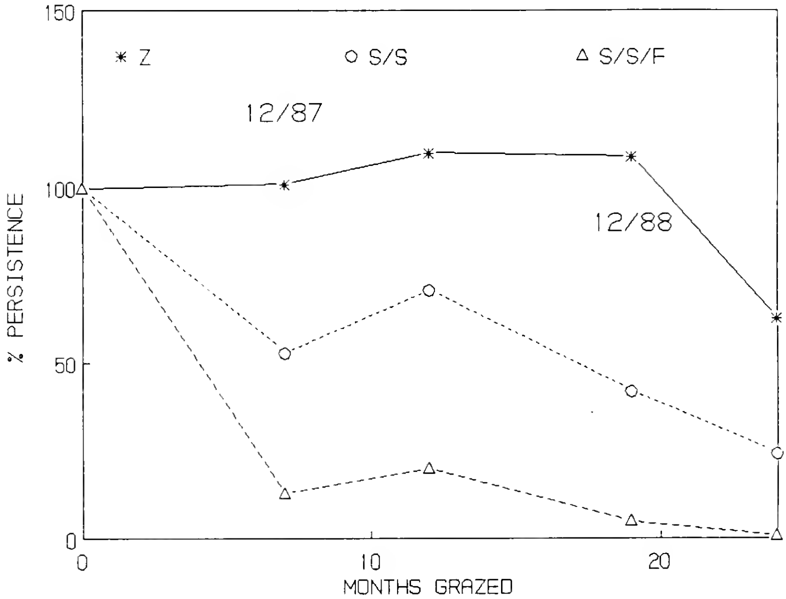

Fig. 10. Mean percent persistence of <u>Vigna adenantha</u> starting 22 May 1987 under zero (Z), spring/summer (S/S) and spring/summer/fall (S/S/F) grazing treatments.

elliottii, this recovery may have been due to stored non-structural carbohydrate reserves which were used to put out new growth before heavy grass competition and grazing occurred in early spring.

By May 1989, the late frost and early spring drought which severely affected several of the other species also combined to reduce Vigna adenantha populations in all grazing treatments. The s/s/f population, already small in December 1988, essentially disappeared. The s/s treatment had only 24% of its original population remaining, lower than the ungrazed treatment. With the onset of summer rains, however, both the s/s and the ungrazed treatments were expected to regain a considerable amount of their original vigor.

Persistence Among Perennials, 1987-1989

Although of limited interest to grazed pastures, it is interesting to note that by the end of the 1987 grazing season Alysicarpus vaginalis and Vigna adenantha populations increased while the others decreased in the ungrazed treatments (refer to Table 4 for actual figures as well as to Fig. 11 for December 1987 and Fig. 12 for December 1988 during the discussion in this section). Desmanthus virgatus and Galactia elliottii especially showed considerable

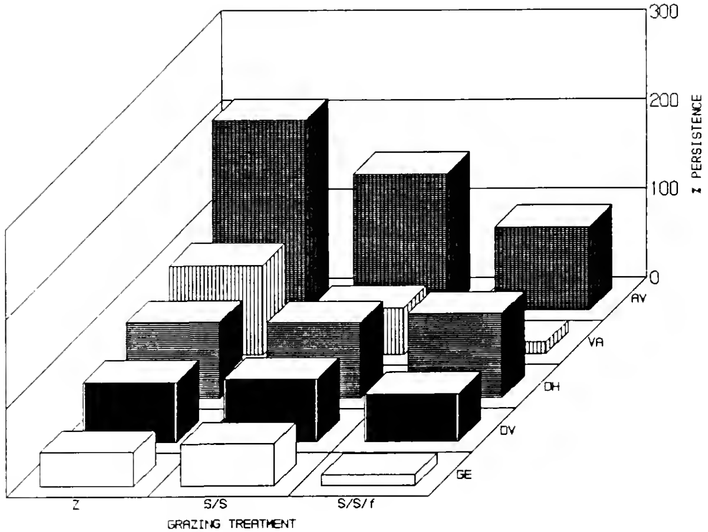

Fig. 11. Mean persistence of perennials <u>Alysicarpus vaginalis</u> (AV), <u>Desmodium heterocarpon</u> (DH), <u>Desmanthus virgatus</u> (DV), <u>Galactia elliottii</u> (GE) and <u>Vigna adenantha</u> (VA) under zero (Z), spring/summer (S/S) and spring/summer/fall (S/S/F) grazing treatments on December 1987 using May 1987 as a base date.

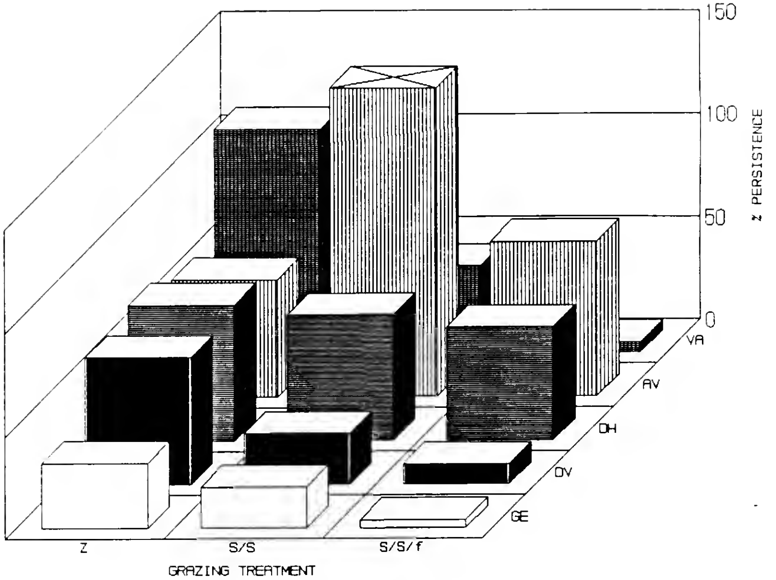

Fig. 12. Mean persistence of perennials Alysicarpus vaginalis (AV), Desmodium heterocarpon (DH), Desmanthus virgatus (DV), Galactia elliottii (GE) and Vigna adenantha (VA) under zero (Z), spring/summer (S/S) and spring/summer/fall (S/S/F) grazing treatments on December 1988 using May 1987 as a base date.

decline the first grazing season under nothing more than the local climatic and edaphic conditions, native herbivores as well as grass competition. Desmanthus virgatus, however, was not different (P=0.01) from the other perennials with the exception of Alysicarpus vaginalis.

In the s/s treatment at this first date, the decumbent A. vaginalis showed a greater ability to persist and increase than any of the others (P=0.0007). Again, this might be an artificial increase due to its late sprouting and therefore low numbers at the base 1987 spring date. Desmodium heterocarpon, equally capable of exhibiting prostrate growth habits, had the next highest persistence although it and the remaining three perennials were not different (P>0.05) from each other. Not surprisingly, the two decumbent species were the most persistent in 1987 under the s/s/f grazing, with both showing values in the nineties. Desmanthus virgatus was lower (P>0.05) at 54% but also higher (P<0.05) than the two remaining perennials, Galactia elliottii and Vigna adenantha. It is important to note that these last two, the species which suffered most under continuous growing-season grazing, were both viney climbers.

The five-month rest from grazing during the winter months, a period when little grass grows in Florida pastures, changed the picture considerably in the zero grazing treatment (P=0.04 for that date). By May 1988, Desmodium heterocarpon as well as the early spring growing

Galactia elliottii and Vigna adenantha showed high persistence values of over 85% while the remaining Alysicarpus vaginalis and Desmanthus virgatus both exhibited an inferior presence.

After the winter period and before cattle were added to the trial in the second grazing year, the s/s plots remained essentially the same in terms of relative persistence. The two major exceptions were a considerable decrease in D. virgatus, making it inferior to all other species, and an equal degree of increase in Vigna adenantha.

Alysicarpus vaginalis, Desmodium heterocarpon and Vigna adenantha populations remained constant relative to each other in the post-winter, May 1988 s/s/f treatment (P=0.001). Desmanthus virgatus, 25%, and Galactia elliottii, 51%, switched positions on the relative persistence scale with the first species decreasing considerably to make it numerically indistinguishable (P>0.05) from Vigna adenantha's 20% and the latter's 51% making it less (P<0.05) persistent than the decumbent Alysicarpus vaginalis and Desmodium heterocarpon.

At the December 1988 reading, following three year's growth and two seasons of grazing, Alysicarpus vaginalis lost the most number of plants relative to the readings one year earlier in the ungrazed treatment. Only 27% of the plants survived. This put Vigna adenantha's 110% persistence higher than all the rest at the ungrazed treatment level and Galactia elliottii's 32% lower ($\underline{P}$=0.005) than any of the other perennials.

Although there was a general decrease in numbers for all species except Alysicarpus vaginalis at this date, the general picture remained the same after the second year of s/s grazing ($\underline{P}$=0.02). Overall, the average persistence showed a steady decline from an average 82% persistence at the end of 1987 down to an average 61% survival after 1988.

In the s/s/f treatment, Galactia elliottii and Vigna adenantha continued to decline and were joined by Desmanthus virgatus at the bottom of the scale on December 1988. Desmodium heterocarpon also declined but at 55% was higher than the above three species. The other species with a tendency for decumbent growth, Alysicarpus vaginalis, had the highest ($\underline{P}$=0.001) survival at 75% although that too was inferior to its December 1987 showing.

The late frost and early spring drought prior to the May 1989 reading changed the picture considerably in the ungrazed control. Alysicarpus vaginalis and Desmodium heterocarpon suffered further population reductions and the first species essentially disappeared. Unless these two were able in the subsequent months to recover dramatically from hidden crowns or seed reserves, this would indicate that these species were unable to survive without defoliation of competing grasses.

At the May 1989 date Desmanthus virgatus and Vigna adenantha under no grazing showed a higher ($\underline{P}$=0.0001) persistence than the two species discussed in the preceding paragraph. In the case of the V. adenantha especially, effects of the frosts and drought were apparent. Only Galactia elliottii managed to exceed its original May 1987 numbers to show that, as a native, it is adapted to local conditions and periodic stresses once well established. While other broadleaf species and grasses displayed visible signs of drought stress, this viney species actually produced new shoots and covered its wilted neighbors.

In the s/s treatment G. elliottii again topped the list at 52% survival, over twice the persistence of any other species ($\underline{P}$=0.01). Among the remaining perennials, no differences ($\underline{P}$>0.05) in population persistence existed under the fall deferment.

Under the s/s/f treatment, the native G. elliottii again showed a strong regeneration from roots that were essentially denuded of all top-growth by grazing the previous fall. This became readily apparent when the 4% survival of December 1988 was compared to the greatly improved 55% following five months of cold, frosts and low precipitation. Individual plants in this treatment were considerably less vigorous than those of the two other treatments, however. None of the other perennial species' population matched this recovery rate in either numbers or vigor. Desmodium heterocarpon, at 18%, was the closest but was not different ($P>0.05$) from the other three perennials.

Persistence Within Annuals, 1987-1989

Although Macroptilium lathyroides is a weak perennial, stands in Florida survive from year to year primarily on the basis of abundant seed production and subsequent germination. For the purposes of this discussion, then, it will be included in the same group as Aeschynomene americana. Since interaction between grazing and species existed at all dates ($P<0.01$), simple effects are discussed below.

Persistence of Macroptilium lathyroides after one growing season and one grazing season showed distinct treatment effects ($P=0.0002$; Table 5). Zero grazing showed the best cover at 60%. The s/s grazing treatment, at 36%, was lower than the ungrazed but also higher than the s/s/f regime which showed only a 14% persistence. Plant counts made after the winter months were comprised mainly of perennating plants which persisted despite frost kill of the upper growth and very young seedlings. Other than a near 50% population loss in the ungrazed treatment, little change occurred (Fig. 13) over the winter. Again, etiolated and exposed growth in the grass-choked, ungrazed treatment or

Table 5. Mean percent survival comparison within and among Macroptilium lathyroides (ML) and Aeschynomene americana (AA) under zero (Z), spring/summer (S/S) and spring/summer/fall (S/S/F) grazing treatments using May 1987 as a base date.

Date	Grazing regime	ML		AA	
Dec. 1987	Z	60a[†]	A[§]	24ab	B
	S/S	36b	A	26a	A
	S/S/F	14c	A	14b	A
May 1988	Z	31a	A	4b	B
	S/S	26a	A	16a	B
	S/S/F	13b	A	16a	A
Dec 1988	Z	32a	A	0a	B
	S/S	27a	A	4a	B
	S/S/F	3b	A	0a	B
May 1989	Z	11a	A	0a	B
	S/S	3b	A	0a	B
	S/S/F	0b	A	0a	A

†Means within columns at each date differ ($P<0.05$) if not followed by a common lower case letter according to Duncan's Multiple Range Test.

§Means within lines at each date differ ($P<0.05$) if not followed by a common upper case letter according to Duncan's Multiple Range Test.

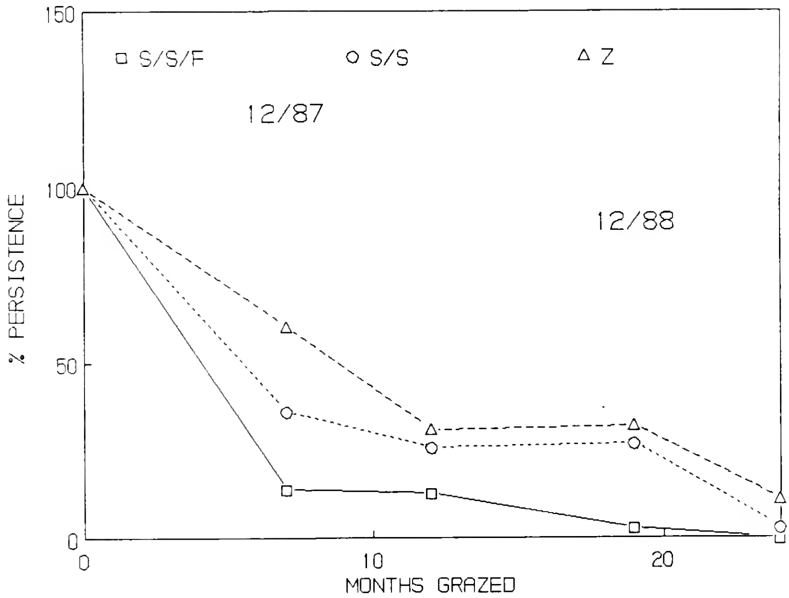

Fig. 13. Mean percent persistence of <u>Macroptilium lathyroides</u> starting 22 May 1987 under zero (Z), spring/summer (S/S) and spring/summer/fall (S/S/F) grazing treatments.

actual colder conditions in the dense herbage may have made this species more vulnerable to cold temperatures.

Other than a steady decrease in s/s/f plant persistence, the December 1988 survival values of M. lathyroides were little changed from the May 1988 readings. The early and late frosts, as well as the unusually droughty early spring, may have contributed to a continued population decline by the May 1989 plant count. At that date no plants survived in the s/s/f treatment and only 3% of the original population either survived or had been replaced through reseeding. The ungrazed control, however, maintained an 11% persistence which was higher (P=0.004) than the two grazed treatments.

Aeschynomene americana had the highest mean persistence under the s/s grazing regime at the December 1987 reading (Table 5 and Fig. 14), although this was not different (P>0.05) from the zero grazed plots. The s/s/f plots showed the lowest persistence although they were not different (P>0.05) from the zero grazed plants. In May 1988, after the winter stress period, seedlings in the s/s and s/s/f treatments were not different (P>0.05) from each other and were both superior (P<0.05) to the zero treatment.

After two grazing seasons, by December 1988, there was essentially no persistence of A. americana (Fig. 15 shows this steady decline). Only the s/s treatment had any survivors at 4%. But this was not different (P=0.29) from

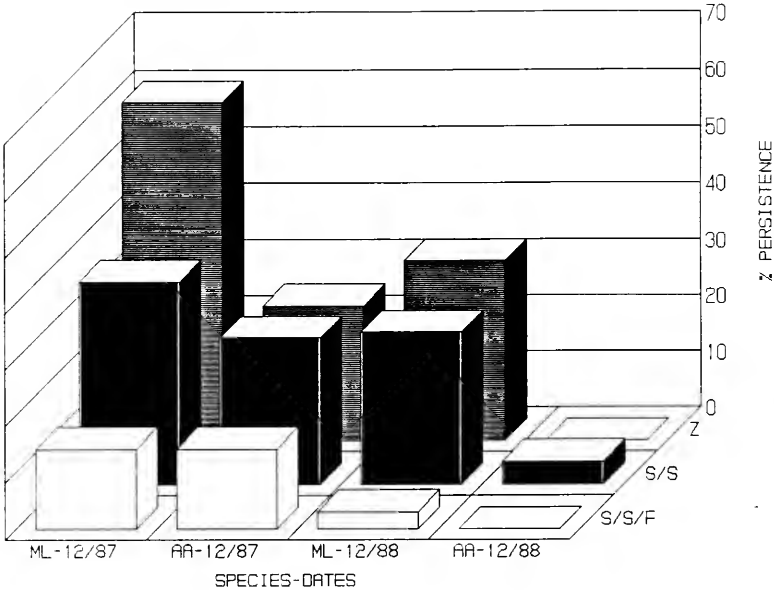

Fig. 14. Mean percent persistence of Macroptilium lathyroides (ML) and Aeschynomene americana (AA) on December 1987 and December 1988 under zero (Z), spring/summer (S/S) and spring/summer/fall (S/S/F) grazing treatments using May 1987 as a base.

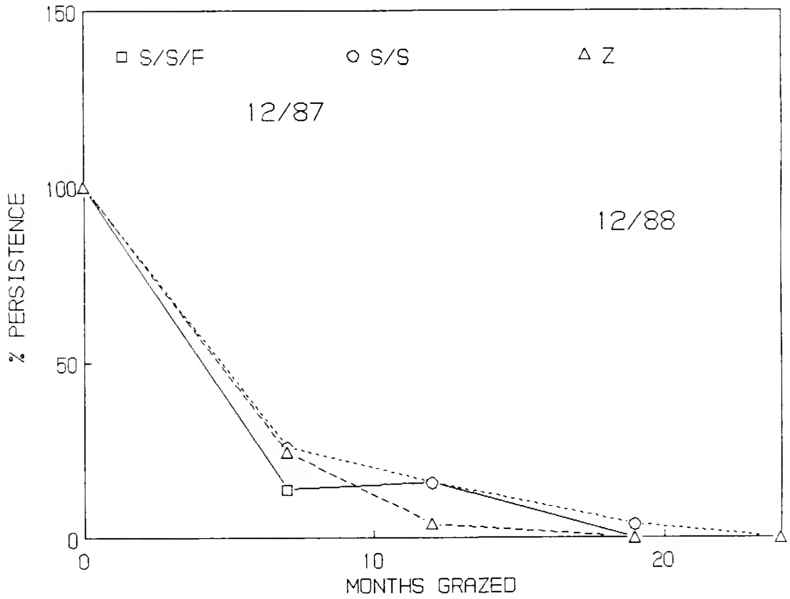

Fig. 15. Mean percent persistence of *Aeschynomene americana* starting 22 May 1987 under zero (Z), spring/summer (S/S) and spring/summer/fall (S/S/F) grazing treatments.

the other two treatments which both showed no plants at all. This situation was not changed by the winter of 1988-1989. All treatments showed no persistence at this date. It should be noted, however, that seeds of this species do not normally germinate and persist in numbers until well into the wet, hot summer months.

Persistence Among Annuals, 1987-1989

In the ungrazed treatment, Macroptilium lathyroides exhibited superior persistence ($P=0.01$) to Aeschynomene americana at the December, 1987 reading (Table 5). There were no differences ($P>0.33$) in either of the two grazed treatments for both these species.

Following winter cold stress, the relative survival of the two species remained the same at the ungrazed level despite a decrease in the numbers of both entries. In the s/s strip plots, however, Macroptilium lathyroides showed a higher ($P<0.05$) survival and perennation although this trend did not appear in the s/s/f treatment ($P=0.64$).

By the end of the second year, December 1988, both annuals showed a steady decline in population compared to a year earlier. This decline was not as severe for M. lathyroides as with Aeschynomene americana (Fig. 14) since the first exhibited superior ($P<0.05$) persistence through reseeding in both grazed treatments.

After the hard frosts and low precipitation of the intervening months, May 1989 plant populations in all treatments for both species declined except where they were already zero. *Macroptilium lathyroides* in the ungrazed treatment was the only appreciable plant population remaining with 11% persistence. Caution should be used in drawing conclusions from the May data since germination and establishment of these species is typically limited prior to summer months.

Pot Study

Winter Harvest

Since there was an interaction between species and treatment in all dependent variables ($P<0.02$), except herbage nitrogen mass ($P=0.54$), the discussions and tables in this section will be concerned solely with the simple effects of this experiment.

Root mass

Galactia elliottii and *Desmanthus virgatus* showed similar treatment effects on root mass with no difference ($P>0.05$) between the early and extended clipping treatments in either of these two species (Table 6). There was,

Table 6. Mean root mass, root total non-structural carbohydrate (TNC) percent and root TNC mass of Galactia elliottii, Desmodium heterocarpon and Desmanthus virgatus following autumn clipping treatments.

Species	Clipping treatment	Root mass	TNC%	TNC mass
		g	%	g
G. elliottii	Extended†	2.76b§	25.5b	0.73b
	Early	2.86b	25.7b	0.72b
	Control	5.67a	33.7a	1.92a
D. virgatus	Extended	2.36b	23.0ab	0.55b
	Early	2.55b	22.1b	0.57b
	Control	4.77a	25.3a	1.20a
D. heterocarpon	Extended	3.12a	12.1a	0.37ab
	Early	3.80a	12.0a	0.46a
	Control	3.40a	9.8b	0.32b
G. elliottii	Extended	2.76a	25.5a	0.73a
D. virgatus		2.36a	23.0b	0.55ab
D. heterocarpon		3.12a	12.1c	0.37b
G. elliottii	Early	2.86b	25.7a	0.72a
D. virgatus		2.55b	22.1b	0.57ab
D. heterocarpon		3.80a	12.0c	0.46b
G. elliottii	Control	5.67a	33.7a	1.92a
D. virgatus		4.77b	25.3b	1.20b
D. heterocarpon		3.39c	9.8c	0.32c

†Extended clipping was six clippings at 2-wk intervals, early clipping included only the first three clippings and the control was never clipped.

§Means within columns for each division differ ($P<0.05$) if not followed by a common letter according to Duncan's Multiple Range Test.

however, a large difference ($P<0.05$) between these two treatments and the unclipped control. Desmodium heterocarpon showed no differences ($P=0.14$) between treatments (Fig. 16). This may in part be because this species was observed to flower, seed and senesce much more than either of the other two. Desmanthus virgatus was not observed to senesce at all throughout the experiment but continued to put out new green growth continuously.

All three species reacted in much the same way to the extended clipping treatment ($P=0.15$). In the early clipping treatment, however, Desmodium heterocarpon had a higher ($P=0.002$) root mass than either of the other two species, perhaps paralleling the earlier senescing which favored reserves in the roots (Table 6). Galactia elliottii had the largest root mass in the unclipped treatment, developing a xylopod (enlarged taproot, Schultze-Kraft and Giacometti, 1979) even in weakly developed plants. Desmanthus virgatus had the next largest mass, smaller than Galactia elliottii but also heavier than Desmodium heterocarpon which had the smallest root system. This last species, in marked contrast to the other two, exhibited a much more extensive secondary, fibrous root system.

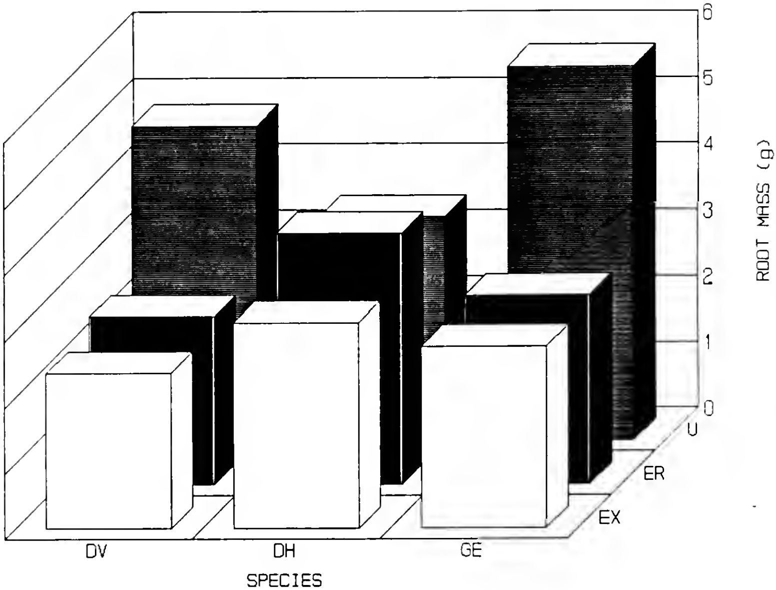

Fig. 16. Mean root mass of <u>Galactia elliottii</u> (GE), <u>Desmodium heterocarpon</u> (DH), and <u>Desmanthus virgatus</u> (DV) under extended clipping (EX), early clipping (ER) and unclipped (U) treatments.

Root total non-structural carbohydrate percent

Galactia elliottii had a higher (*P*=0.0001) TNC percent in the unclipped treatment with no differences (*P*>0.05) between the two clipped treatments (Table 6). This last phenomenon may in part be due to the tendency of this species tended to drop its leaves and stop growth in all treatments about the time that the clippings in the early clipping treatment were terminated. If the treatments had begun a little earlier in the season, differences between the early and the extended clipping treatments may have developed.

This was also the case with *Desmodium heterocarpon* except that in this species the unclipped treatment was lower (*P*=0.002) than the two clipped treatments (Fig. 17). This difference between the two species may be explained by the fact that the clipped plants were less dormant at the winter harvest since they were unable to complete seed production as well as did the unclipped control. There was, perhaps, a much larger percentage of dead root component in the unclipped plants which may have brought the TNC percent down.

Desmanthus virgatus, being more metabolically active during these late fall months than the other species, showed less distinct differences (*P*=0.09) between the clipped and the unclipped treatments. The unclipped control had higher

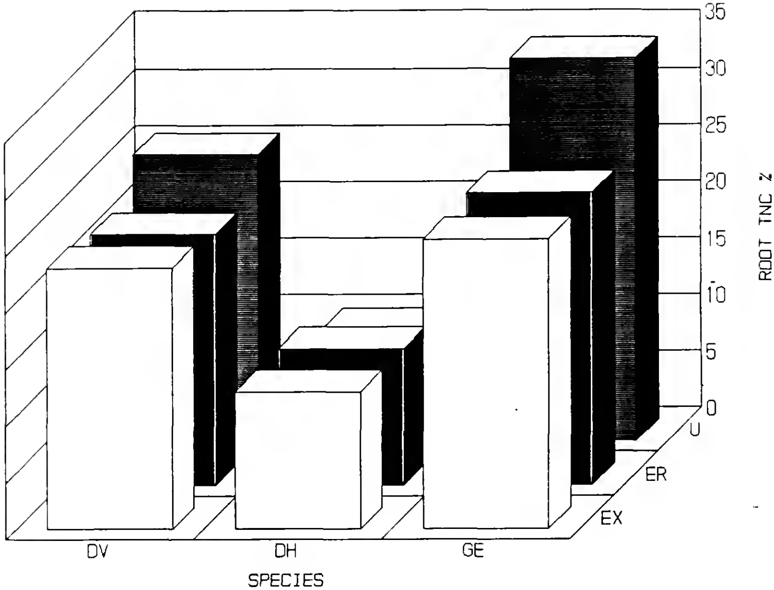

Fig. 17. Mean root total non-structural carbohydrate (TNC) percent of Galactia elliottii (GE), Desmodium heterocarpon (DH), and Desmanthus virgatus (DV) under extended clipping (EX), early clipping (ER) and unclipped (U) treatments.

TNC than did the early clipping treatment but it was not different from the extended clipping treatment.

Galactia elliottii had the highest TNC percentages in all treatments followed by Desmanthus virgatus which in turn exhibited higher percentages than Desmodium heterocarpon in all three treatments. This indicates that the species genetic differences (P=0.0001 under all treatments) in terms of non-structural carbohydrate percentages under any conditions were likely very distinct.

Root total non-structural carbohydrate mass

This response was attained by multiplying the two already mentioned dependent variables. It is natural, then, that the results are similar to the other two (see Table 6 and Fig 18). Galactia elliottii TNC follows the same trend as the other two parameters, with the unclipped treatments showing over 100% higher (P=0.0001) TNC mass than the other two treatments. Desmanthus virgatus showed the same differences (P=0.0001) as in the case of its root mass. Desmodium heterocarpon, as in the case of the two originating responses, showed no differences (P>0.05) between the two clipping treatments but also showed no differences (P>0.05) between the extended clipping treatment and the unclipped treatment. No readily apparent explanation exists for this last relationship.

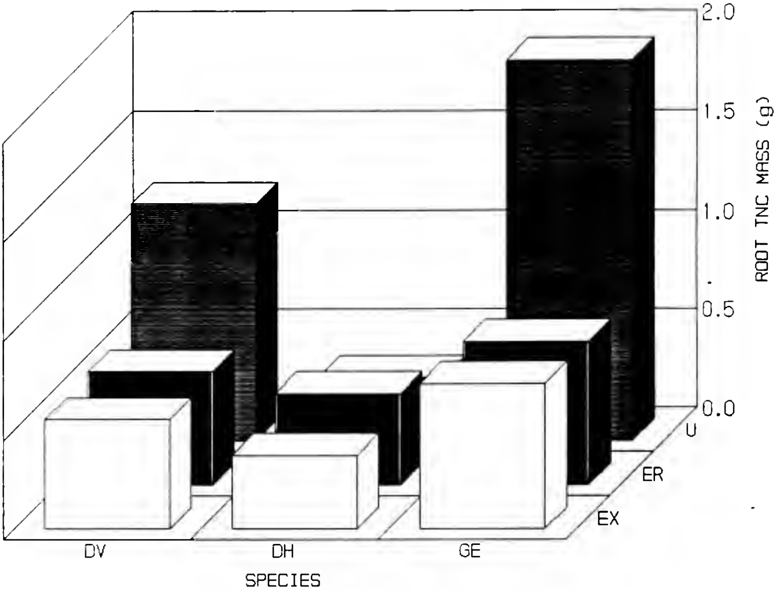

Fig. 18. Mean root total non-structural carbohydrate (TNC) mass of Galactia elliottii (GE), Desmodium heterocarpon (DH), and Desmanthus virgatus (DV) under extended clipping (EX), early clipping (ER) and unclipped (U) treatments.

As might be expected after examination of the individual species, the extended and early clipping treatments were similar (P=0.007 and P=0.01 respectively) when responses were analyzed by clipping treatment. Galactia elliottii had the highest mass but was not different from Desmanthus virgatus (Table 6). In the case of the unclipped control as well, the same species differences (P=0.0001) reasserted themselves with Galactia elliottii showing the highest root TNC mass followed by Desmanthus virgatus and then Desmodium heterocarpon.

Herbage mass

There were no differences P>0.05 between the two clipped treatments in all three species (Table 7). This occurred, perhaps, because the rest period following the early clipping treatment was not long enough for differences in recovery from the extended clipping treatment to surface in the cool fall weather. Galactia elliottii also showed no differences (P=0.47 for all clipping treatments) between the two clipped treatments and the unclipped control, again, perhaps because of normal fall senescence. The other two species, however, did exhibit higher P<0.002 herbage masses in the unclipped control (Fig 19).

Table 7. Mean herbage mass, herbage nitrogen percent and herbage nitrogen mass of Galactia elliottii, Desmodium heterocarpon and Desmanthus virgatus following autumn clipping treatments.

Species	Clipping treatment	Herbage mass	Herbage N%	Herbage N
		--g--	--%--	--g--
D. heterocarpon	Extended†	2.29b§	2.13a	0.047a
	Early	2.27b	2.13a	0.047a
	Control	2.90a	1.78b	0.051a
D. virgatus	Extended	2.41b	2.13a	0.048a
	Early	2.49b	1.92b	0.045a
	Control	3.95a	1.20c	0.047a
G. elliottii	Extended	0.59a	1.89a	0.011ab
	Early	0.69a	1.86a	0.013a
	Control	0.61a	1.33b	0.008b
D. heterocarpon	Extended	2.29a	2.14a	0.047a
D. virgatus		2.41a	2.13a	0.048a
G. elliottii		0.59b	1.87b	0.011b
D. heterocarpon	Early	2.27a	2.13a	0.047a
D. virgatus		2.49a	1.92b	0.045a
G. elliottii		0.69b	1.86b	0.013b
D. heterocarpon	Control	2.90b	1.78a	0.051a
D. virgatus		3.95a	1.20b	0.047a
G. elliottii		0.61c	1.33b	0.008b

†Extended clipping was six harvests at 2-wk intervals, early clipping included only the first three clippings and the control was never clipped.

§Means within columns for each division differ ($P<0.05$) if not followed by a common letter according to Duncan's Multiple Range Test.

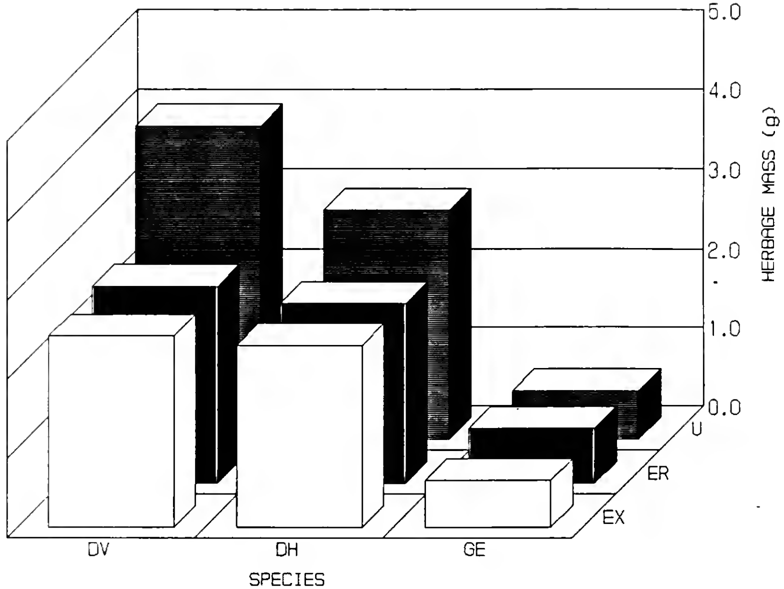

Fig. 19. Mean herbage mass of <u>Galactia elliottii</u> (GE), <u>Desmodium heterocarpon</u> (DH), and <u>Desmanthus virgatus</u> (DV) under extended clipping (EX), early clipping (ER) and unclipped (U) treatments.

In the extended clipping treatment (*P*=0.0001), as in the early clipping treatment (*P*=0.0001), *Desmanthus virgatus* and *Desmodium heterocarpon* were undifferentiated (*P*>0.05) and both had greater herbage weights than the *Galactia elliottii* plants (Table 6). In the control, *Desmanthus virgatus*' continued growth through the cool months resulted in 26% greater herbage than *Desmodium heterocarpon* which in turn was 475% greater than *Galactia elliottii*.

Herbage nitrogen percent

In the case of both *Galactia elliottii* (*P*=0.0001 for all clipping treatments) and *Desmodium heterocarpon* (*P*=0.0001 for all clipping treatments), herbage nitrogen percentages of the two clipped treatments were not different (*P*>0.05) from each other and were greater than nitrogen percentages of the unclipped plants of both species (Table 7). *Desmanthus virgatus*, in one of the few instances in this experiment in which a response variable showed a difference (*P*=0.0001) between the two clipping treatments, had differences between all three treatments. The extended clipping treatment, with its continually regrowing plants, topped the list with 2.13% nitrogen followed by the early clipping treatment with 1.92% nitrogen and the unclipped control with the woodiest stems at 1.20% nitrogen (Fig. 20).

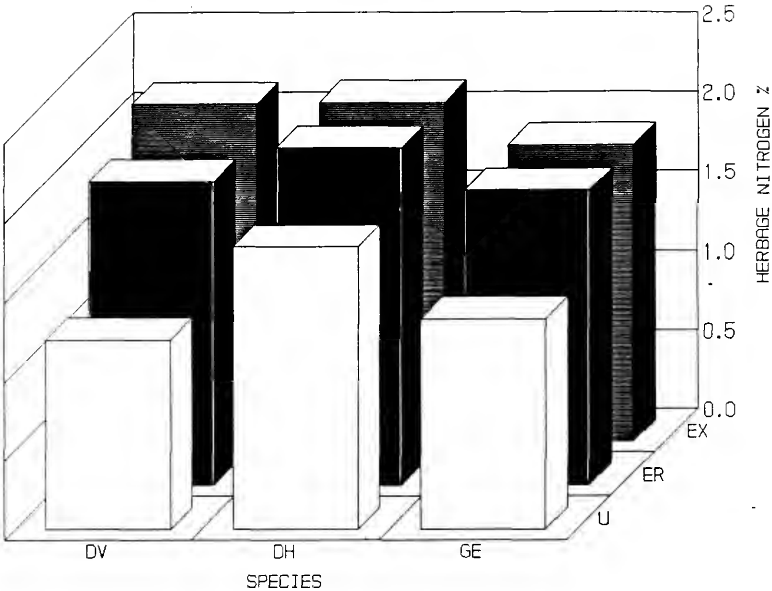

Fig. 20. Mean herbage nitrogen percent of _Galactia elliottii_ (GE), _Desmodium heterocarpon_ (DH), and _Desmanthus virgatus_ (DV) under extended clipping (EX), early clipping (ER) and unclipped (U) treatments.

When species were compared in the extended clipping treatment (P=0.006), there were no differences P>0.05 between Desmodium heterocarpon and Desmanthus virgatus (Table 7). Due most likely to the continued defoliation in this treatment, Desmodium heterocarpon was unable to produce flowers as much as it did with the unclipped control and therefore was forced, perhaps, to maintain its leafiness and consequently higher nitrogen percent.

When the species were compared in the early clipping treatment (P=0.004), D. heterocarpon again had the highest nitrogen percent. In this case, however, it had higher values than either of the other two species which were not different (P>0.05) from each other. This same trend appears in the unclipped control although levels for all species are lower than in the early clipping treatment.

Herbage nitrogen mass

This measurement was a product of the two previously discussed responses with results that appear in Table 7 (also Fig. 21). Interestingly, the differences in mass and nitrogen percent compensate in Desmodium heterocarpon and Desmanthus virgatus so that there are no differences (P=0.56 and P=0.71 respectively) among any of the three clipping treatments in these two species. Herbage nitrogen mass of Galactia elliottii (P=0.03 for clipping treatment effects)

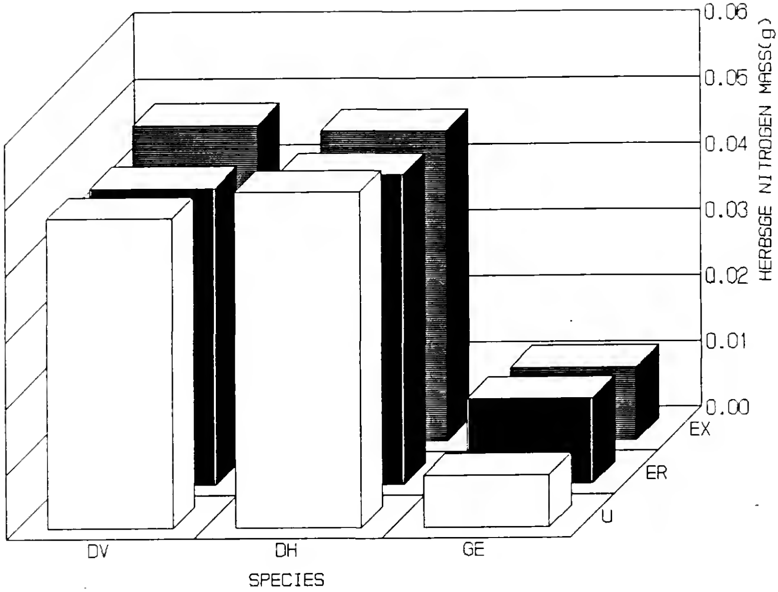

Fig. 21. Mean herbage nitrogen mass of Galactia elliottii (GE), Desmodium heterocarpon (DH), and Desmanthus virgatus (DV) under extended clipping (EX), early clipping (ER) and unclipped control (U) treatments.

was highest in the early clipping treatment although the extended clipping treatment was not different from this treatment. The unclipped control resulted in the lowest nitrogen mass although this was not lower ($P>0.05$) than the extended clipping treatment.

Leaf mass

Clipping treatment had no effect $P=0.58$ on leaf mass of Desmanthus virgatus (Table 8). In Desmodium heterocarpon treatments were different ($P=0.0001$) although no differences $P>0.05$ appeared between the two clipped treatments (Table 8). Only in Galactia elliottii was the leaf mass of the early clipping treatment higher ($P=0.02$) than the unclipped control (Fig. 22). G. elliottii, with its tendency to drop leaves prior to the cold winter months, would more likely have had more usable leaf material if it had been harvested before leaf-dropping.

In all regimes, Desmanthus virgatus was consistently the most ($P=0.0001$) productive followed by Desmodium heterocarpon and then Galactia elliottii. The only exception was in the early clipping treatment in which there were no differences ($P>0.05$) between the two most productive species.

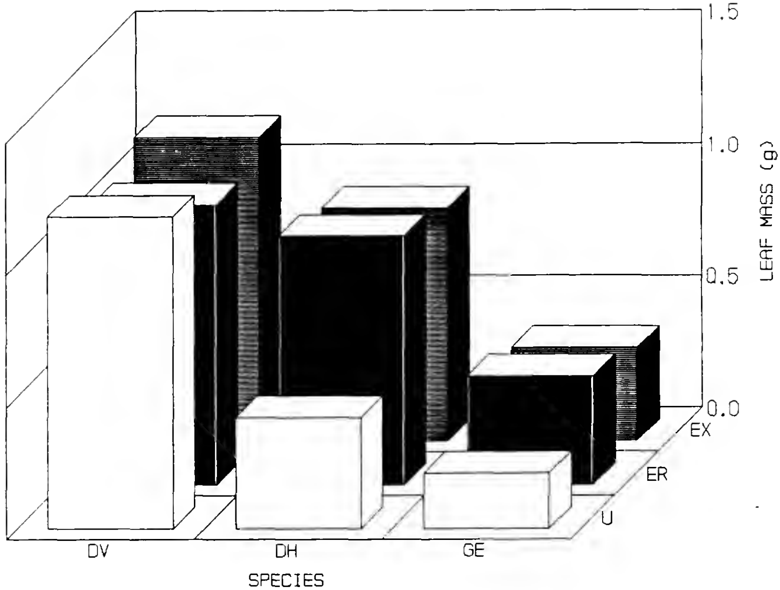

Fig. 22. Mean leaf mass of *Galactia elliottii* (GE), *Desmodium heterocarpon* (DH), and *Desmanthus virgatus* (DV) under extended clipping (EX), early clipping (ER) and unclipped control (U) treatments.

Table 8. Mean leaf mass, leaf-stem ratio and flower and legume mass of Galactia elliottii, Desmodium heterocarpon and Desmanthus virgatus following autumn clipping treatments.

Species	Clipping treatment	Leaf mass	Leaf-stem	Flower & pod mass
		--g--		--g--
G. elliottii	Extended†	0.35ab§	1.50a	0.0a
	Early	0.41a	1.88a	0.0a
	Control	0.21b	0.58b	0.0a
D. heterocarpon	Extended	0.88a	1.11a	0.47b
	Early	0.94a	1.19a	0.39b
	Control	0.42b	0.30b	1.03a
D. virgatus	Extended	1.15a	0.93a	0.00b
	Early	1.06a	0.86a	0.01b
	Control	1.18a	0.49b	0.22a
D. heterocarpon	Extended	0.88b	1.11b	0.47a
D. virgatus		1.15a	0.93b	0.00b
G. elliottii		0.35c	1.50a	0.00b
D. heterocarpon	Early	0.94a	1.19b	0.39a
D. virgatus		1.06a	0.86b	0.01b
G. elliottii		0.41b	1.88a	0.00b
D. heterocarpon	Control	0.42b	0.30b	1.03a
D. virgatus		1.18a	0.49ab	0.22b
G. elliottii		0.21c	0.59a	0.00c

†Extended clipping was six harvests at 2-wk intervals, early clipping included only the first three clippings and the control was never clipped.

§Means within columns for each division differ ($P<0.05$) if not followed by a common letter according to Duncan's Multiple Range Test.

Leaf-stem ratio

Clipped plants exhibited much higher ($P<0.0008$) leaf-stem ratios than the unclipped control for all species (Table 8). No differences ($P>0.05$), however, were measured for leaf-stem ratios between the two clipped treatments for any of the species (Fig. 23).

When a comparison was made among species, *Desmodium heterocarpon* and *Desmanthus virgatus* were not different ($P>0.05$) from each other in all treatments but produced lower ($P<0.05$) leaf-stem ratios than did *Galactia elliottii*. This last species is the only viney entry and would normally have to invest less in structural support than the two more upright species. The only exception was in the unclipped control in which *Desmanthus virgatus* and *Galactia elliottii* were not different ($P>0.05$).

Flower and pod mass

Galactia elliottii was not observed to produce flowers in this study (Table 8). *Desmanthus virgatus*, normally a heavy seed producer in the field, likewise did not produce many flowers or pods (Fig. 24). Only the unclipped control was able to store up sufficient energy to invest in seed production (Table 8). Clipping treatment was therefore observable ($P=0.0001$).

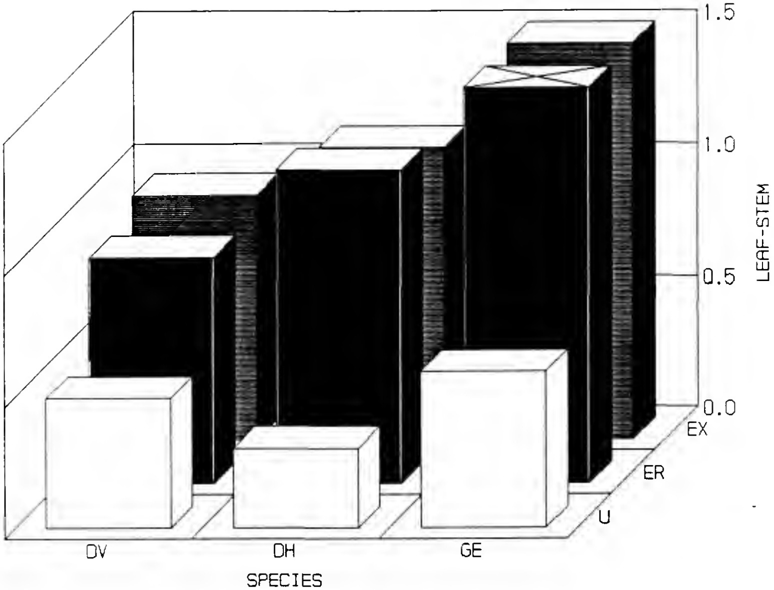

Fig. 23. Mean leaf-stem ratio of _Galactia elliottii_ (GE), _Desmodium heterocarpon_ (DH), _Desmanthus virgatus_ (DV) under extended clipping (EX), early clipping (ER) and unclipped control (U) treatments.

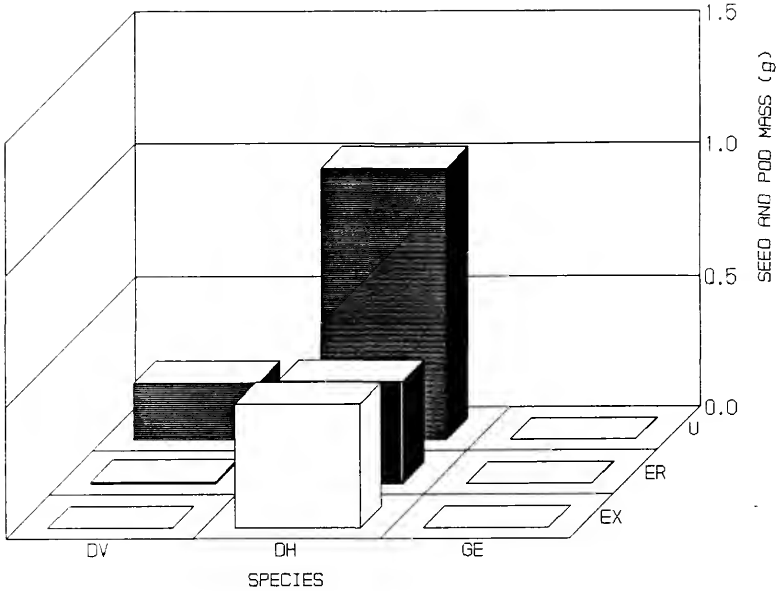

Fig. 24. Mean seed and pod mass of *Galactia elliottii* (GE), *Desmodium heterocarpon* (DH), and *Desmanthus virgatus* (DV) under extended clipping (EX), early clipping (ER) and unclipped control treatments.

Desmodium heterocarpon, on the other hand, flowered and set seed on almost every plant in the study and showed a clipping treatment effect (P=0.0001). There was, again, no difference (P>0.05) between the flower and pod production in the two clipped treatments. Only the unclipped control was different (P<0.05), producing over twice as much material as the plants in either clipped treatment.

Spring Harvest

There were no three-way interactions among species, initial autumn clipping treatments and winter harvest in the variables measured at the spring harvest date (P>0.58). Root and herbage mass showed interactions between species and winter harvest (P=0.0001 for both) as well as between winter harvest and autumn clipping treatments (P=0.008 for root and P=0.01 for herbage). Herbage nitrogen weight showed an interaction between species and winter harvest (P=0.02), while herbage nitrogen percent showed that an interaction between species and autumn clipping treatments still existed (P=0.005) after the winter period. Each of these interactions is examined separately.

Root mass: species X winter harvest

In *Galactia elliottii* and *Desmanthus virgatus*, winter harvest did not produce effects on root mass (Table 9) when compared to the unharvested control (*P*=0.10 and *P*=0.07 respectively). *Desmodium heterocarpon*, however, did show a measurable effect, with the unharvested plant root weights showing over twice the mass of the winter-harvested plant roots (*P*=0.0001).

When species were compared within the winter-harvest treatments, differences (*P*=0.0001) also appeared. In the winter harvested plants, *D. heterocarpon* showed considerably less (*P*<0.05) root mass than the other two species. In the unharvested plants, *Desmanthus virgatus* was higher than the other two entries (*P*<0.05). The change in species relative differences within the winter harvested treatment and the unharvested control indicated that more than just species-specific differences contributed to root mass differentiation.

Root mass: autumn clipping X winter harvest

Winter harvest had no effect on root mass from either the extended clipping treatment (*P*=0.16) or the early clipping treatment (*P*=0.58; Table 10). Only in the autumn

Table 9. Mean Root mass and herbage mass of *Galactia elliottii*, *Desmodium heterocarpon* and *Desmanthus virgatus* allowed 16 wk recovery following winter harvest at 3-cm height and an unharvested control.

Species	Root mass		Herbage mass	
	Control	Harvest	Control	Harvest
	g			
D. virgatus	2.2a†A§	1.8a A	2.1a A	1.3b B
G. elliottii	1.6a B	1.9a A	1.3a B	1.7a A
D. heterocarpon	1.5a B	0.7b B	1.2a B	0.3b C

†Means within lines for each response differ ($P<0.05$) if not followed by a common lower case letter according to Duncan's Multiple Range Test.

§Means within columns differ ($P<0.05$) if not followed by a common upper case letter according to Duncan's Multiple Range Test.

Table 10. Mean root mass and herbage mass of _Galactia elliottii_, _Desmodium heterocarpon_ and _Desmanthus virgatus_ allowed 16 wk recovery after superimposing a winter harvest at 3-cm height and an unharvested control on autumn clipping treatments.

Autumn clipping treatment	Root Mass Control	Root Mass Harvest	Herbage Mass Control	Herbage Mass Harvest
	----------	----------	g ----------	----------
Control¶	2.1a† A§	1.3b A	1.8a A	0.9b B
Extended	1.7a AB	1.5a A	1.5a AB	1.3a A
Early	1.5a B	1.6a A	1.3a B	1.1a AB

¶Extended clipping was six clippings at 2 wk intervals, early clipping included only the first three clippings and the control was never clipped.

†Means within lines for each response differ ($P<0.05$) if not followed by a common lower case letter according to Duncan's Multiple Range Test.

§Means within columns differ ($P<0.05$) if not followed by a common upper case letter according to Duncan's Multiple Range Test.

unclipped control did the winter harvest produce measurable differences (P=0.0009). Here the unharvested control root masses of all species remained larger after winter relative to the winter harvested treatment.

When autumn clipping treatments were compared by winter harvest treatments, no differences (P=0.33) registered in the winter-harvested treatment. Only in the unharvested control were there differences (P=0.006). Here the autumn unclipped control showed a higher root mass mean than the autumn early clipping treatment.

Herbage mass: species X winter harvest

Galactia elliottii herbage mass showed no response (P=0.07) to winter harvest (Table 9). In both the other species, however, the winter harvest decreased herbage growth (both P=0.0001). *Desmodium heterocarpon* showed a large response with a 400% difference between herbage mass in the two treatments.

A comparison among species within each winter harvest treatment indicated differences (P=0.0001 for both harvested and unharvested). In the winter-harvested treatment, *Galactia elliottii* had the largest herbage mass with *Desmanthus virgatus* the next highest which was then followed by *Desmodium heterocarpon* (P<0.05 for all differences). In the unharvested control *Desmanthus virgatus* had the highest

(_P_<0.05) herbage mass followed by the other two species which were not different (_P_>0.05) from each other.

Herbage mass: autumn clipping X winter harvest

Winter harvest treatments did not affect herbage mass in either of the two clipped treatments from the autumn clipping (_P_>0.14 for both; Table 10). Only in the unclipped autumn control was there a difference (_P_=0.0001). Here the winter unharvested control herbage weights averaging twice as much as the winter harvested treatment.

The only difference (_P_=0.0001) among autumn clipping treatments in the unharvested winter treatment was that of the early clipping treatment and the unclipped control where the later was larger (_P_<0.05). In the case of the harvested plants, by contrast, the only difference (_P_=0.07) was between the extended clipping treatment and the unclipped control.

Herbage nitrogen percent: species X autumn clipping

In _Galactia elliottii_ (_P_=0.57) and _Desmanthus virgatus_ (_P_=.96), autumn clipping treatments did not affect (_P_>0.05) nitrogen percent in the herbage following the winter months (Table 11). _Desmodium heterocarpon_, however, did show a lower (_P_=0.0001) nitrogen percent in the unclipped control

Table 11. Mean herbage nitrogen percent of Galactia elliottii, Desmodium heterocarpon and Desmanthus virgatus allowed 16 wk recovery following autumn clipping treatments.

Species	Herbage nitrogen					
	Extended¶		Early		Control	
	---------------%					
G. elliottii	2.07a†	A§	2.04a	A	1.91a	A
D. heterocarpon	1.86a	A	1.87a	A	1.15b	B
D. virgatus	1.44a	B	1.42a	B	1.40a	B

¶Extended clipping was six clippings at 2 wk intervals, early clipping included only the first three clippings and the control was never clipped.

†Means within lines differ ($P<0.05$) if not followed by a common lower case letter according to Duncan's Multiple Range Test.

§Means within each column differ ($P<0.05$) if not followed by a common upper case letter according to Duncan's Multiple Range Test.

either of the two autumn clipping treatments with no differences (*P*>0.05) between the last two.

Differences between species in the autumn clipping treatments (*P*=0.0007 for extended; *P*= 0.001 for early) indicated that in both clipped treatments, *Desmanthus virgatus* had lower (*P*<0.05) nitrogen percentages than the other species. In the autumn unclipped control, *Galactia elliottii* had a higher (*P*=0.002) nitrogen percent than either of the other two species.

Herbage nitrogen mass: species X winter harvest

Galactia elliottii and *Desmanthus virgatus* were unaffected (*P*=0.18 and *P*=0.09 repectively) by winter harvest (Table 12). Only *Desmodium heterocarpon* showed a effect (*P*=0.0004) with over twice as much nitrogen measured in the unharvested control plants than was present in the winter harvested treatment.

When species are compared within the winter harvested treatment, differences (*P*=0.0001) between species existed. *Galactia elliottii* had the highest (*P*<0.05) nitrogen content followed by *Desmanthus virgatus* and then *Desmodium heterocarpon*. In the unharvested control the differences were less distinct (*P*=0.05) with only *Desmanthus virgatus*, with greater nitrogen weights per plant, different from *Desmodium heterocarpon*.

Table 12. Mean herbage nitrogen mass of *Galactia elliottii*, *Desmodium heterocarpon* and *Desmanthus virgatus* allowed 16 wk recovery after being submitted to a winter harvest at 3-cm height and an unharvested control.

Species	Herbage nitrogen mass Control		Harvest	
	---------------g---------------			
G. elliottii	0.10a[†]	AB[§]	0.13a	A
D. virgatus	0.11a	A	0.08a	B
D. heterocarpon	0.07a	B	0.03b	C

†Means within lines differ ($P<0.05$) if not followed by a common lower case letter according to Duncan's Multiple Range Test.

§Means within each column differ ($P<0.05$) if not followed by a common upper case letter according to Duncan's Multiple Range Test.

Correlations Between Winter and Spring Factors

Correlations were computed using winter root TNC mass and root mass as the independent variables and spring herbage mass and herbage nitrogen mass as the dependent variables. Only the values of the winter harvested treatment plants were used since these were thought to most closely parallel the conditions in the pasture and because these, having lost all herbage over a 3-cm height, would be more dependent on root reserves for regrowth. The results are given in Table 13.

Correlation *P*-values on average were lowest for *Galactia elliottii*. Both TNC and root mass showed a positive correlation with spring herbage nitrogen mass. The correlation between winter root mass and spring herbage mass (P=0.10), was closer than that of the winter TNC and the same dependent variable.

Desmodium heterocarpon showed very weak correlation coefficients (P>0.16 for all measurements) Winter root mass, however, was more highly correlated with the two spring responses than was winter TNC.

Spring herbage mass of *Desmanthus virgatus* was negatively correlated with winter root TNC (P=0.07) and winter root mass (P=0.09). Why this correlation was negative, however, may be difficult to explain.

Table 13. Correlation between pre-winter root and root total non-structural carbohydrate (TNC) weights with post-winter herbage mass and herbage nitrogen mass in three forage legumes allowed 16 wk recovery after being subjected to three autumn clipping treatments and winter harvested at 3-cm heights.

Species	Winter factor	Spring factor	Correlation coefficients	P-value
Galactia elliottii	Root TNC mass	Herbage mass	0.35	0.27
		Herbage N mass	0.60	0.04
	Root mass	Herbage mass	0.50	0.10
		Herbage N mass	0.60	0.04
Desmodium heterocarpon	Root TNC mass	Herbage mass	-0.11	0.74
		Herbage N mass	-0.12	0.72
	Root mass	Herbage mass	0.42	0.17
		Herbage N mass	0.41	0.18
Desmanthus Virgatus	Root TNC mass	Herbage mass	-0.54	0.07
		Herbage N mass	-0.41	0.19
	Root mass	Herbage mass	-0.52	0.09
		Herbage N mass	-0.38	0.23

Continued maintenance of minimal green leaves with very little growth during the winter period for both *Desmodium heterocarpon* and *Desmanthus virgatus* may have been a factor in masking any correlations. Although not evaluated, plants with higher underground root structures may have had energy for somewhat greater initial regrowth resulting in greater energy demands and greater depletion during the winter period.

CHAPTER FIVE

DISCUSSION

The three objectives of this study are addressed below in order of original presentation.

Species Persistence under Grazing Management

Previous studies in legume persistence under periodic grazing deferment indicated almost universally beneficial results from rest. In this experiment, the results were not so clear. Some species survived as well under fall grazing as under deferment. Others declined under both treatments. A third group did show treatment effects. Since there were a variety of plant population responses to spring/summer/fall grazing, fall deferred grazing and the ungrazed control, these are discussed below by species.

Aeschynomene americana

This species had difficulties with establishment and very low persistence despite two seedings. Data collection and interpretation also were problematic. Observations from the summer months in which this species was most apparent were of dubious worth since population numbers at this time did not yet reflect the effect of fall deferment for that year. There also was the additional risk of counting seedlings which germinated from original seedings as having originated from the previous year's plant population.

Although it is difficult to extract any conclusions from such low fall plant populations, first year results indicated that fall grazed plots had the lowest plant population survival. This would indicate that seed production would consequently also be the lowest. By the fall of 1988, however, even the benefit derived from the lessened grass competition during summer grazing followed by deferment for seed production in the fall did not allow any mature plant survival or seed setting.

Failure to establish and regenerate may have been related to moisture stress at critical times. Especially at seeding, this species has been documented to succumb to flooding as well as short droughts. Kalmbacher et al. (1988) stated that 7 of 17 plantings studied at Ona AREC failed). Tanner and Terry (1984), however, successfully established this species in unfertilized rangelands in two years with below-average rainfall. Their success may have been due to above-average rainfall in April.

Once established, then, Aeschynomene americana has potential for a wide range of management needs. Quesenberry and Ocaumpaugh (1981) indicated that flowering varied within this and other Aeschynomene species, a trait that might be useful for selecting germplasm tolerant of defoliation further into the fall.

Alysicarpus vaginalis

Despite initially, and perhaps artificially inflated, plant survival numbers in 1987, May 1989 population figures indicated that this entry had difficulty surviving the early spring of 1989. Perhaps, as it did in previous years, seedlings or crown resprouting in response to warmer temperatures and increased moisture may have eventually brought the population numbers back up later in 1989.

Indications were strong, however, that this species was not capable of surviving well under heavy grass competition and, in fact, did better where some grazing occurred. Fall deferment did produce the greatest persistence for this entry up to the end of 1988. Continuously grazed plots, however, did maintain a healthy 75% survival up to this time as well.

Desmanthus virgatus

Although this species had low survival the first grazing season, population decline slowed in subsequent years. By 1989, over 50% of the plants in the ungrazed plots had succumbed to local conditions. Twenty-six percent survived when given the fall period to recover. This was considerably better than the 9% in the May through December grazed plots. This indicated that this upright legume was fairly well adapted to the region once established but required some deferment for good stand persistence. This last point was especially pertinent since seedling survival from its heavy seed production was not observed in the field so that once established plants are lost, they were unlikely to be replaced.

The pot study shed some light on why this species responded to fall deferment. Root mass and non-structural carbohydrate mass were adversely affected by autumn clipping although the 6-wk rest allowed in the early clipping treatment of the pot experiment did not produce a measurable recovery in these two factors.

Desmodium heterocarpon

This entry exhibited very high persistence in all three grazing treatments in the field the first year of grazing. New seedlings were observed even outside the plots. The second year showed a gradual decline in population numbers of all plots which after the late frost and long drought in 1989 decreased even further.

The utility of this species for Central Florida should not be dismissed, however. It should be noted that it was capable of surviving in both continuously grazed and ungrazed plots, making it appear to be a rather versatile legume. Established stands may have the ability to survive periodic spring droughts through heavy seed production. Kretschmer et al. (1976) have observed good persistence of Desmodium heterocarpon under varying conditions but did not determine whether pasture plant survival was due more to perennation or seed production in years with sub-average rainfall.

The pot study indicated that if seed production is important to this species for plant population persistence through periodic climatic stresses, then deferment may be advised. This would not be to increase root storage, largely unaffected by rest, but to allow greater seed set which was greatly curtailed by clipping.

Galactia elliottii

This native legume showed the greatest promise for future use in reseeding range and low-input pastures. Despite what appeared to be rather low population survival every fall, G. elliottii showed a resilience which produced the earliest spring growth, and greatest propagation in certain cases, of any of the legumes studied. Plant populations in the fall-grazed plots were as persistent as in the fall-deferred treatment after two grazing seasons, a characteristic unique in this study. Spring deferment rather than late fall deferment might be what this species requires for good pasture cover and greater likelihood of overcoming the nutritional limitations of the summer slump.

The pot study indicated that this lack of response to fall grazing might be due to a natural dormancy which triggers in early fall. The autumn clipping treatments had a large effect on root weights and non-structural carbohydrate content but no effect on subsequent herbage growth. Lack of a clear relationship between levels of winter root TNC and spring regrowth was probably due to a long recovery period and all treatments providing at least enough energy to meet regrowth needs. This species was observed to develop extensive root systems even in the autumn clipped treatments although these were smaller than the unclipped control. Perhaps originally developed as a response to Florida's cool winters, this characteristic may allow G. elliottii to extract nutrients from herbage for storage in its extensive taproot and rhizome system before destruction due to cold temperatures occurs.

Macroptilium lathyroides

This short-lived perennial, as with the annual included in this study, was dependent on good seed production to maintain and expand its plant population. Its positive response to late season rest was evident in the fact that during the second grazing season of the experiment there were no measurable differences between the ungrazed and the late spring/summer grazed plots. Despite fall deferment, however, it failed to increase or even maintain its original numbers.

Two cautionary notes should be included here, however. First is that poor establishment may have biased results from the start. The second is that the final plant count in May 1989, taken during a prolonged spring drought, was not the best time to measure persistence of a species largely dependent on seed germination for regeneration. As in the case of Aeschynomene americana, spring and late fall dates, when data were collected for all field entries, may not have been the appropriate time to measure population numbers. This short-lived perennial, however, does not exhibit the complete senescence of the true annual.

Vigna adenantha

As *Galactia elliottii* appeared to be the legume of choice for minimally managed pastures, *Vigna adenantha* may have its only potential where grazing management is more intensive. Although a 24% population survival in May 1989 under fall deferment does not seem impressive, the fact that any growth at all occurred combined with its stability in the previous 2 yr gave this entry promise the others did not show.

This species roots at the nodes, thereby ensuring propagation capabilities independent of seed production. This characteristic gave it the added advantage some of the other equally persistent entries did not posses. Whereas some species might take an entire season to set seed and produce good cover, *V. adenantha* appears capable of accomplishing this through vegetative reproduction in a fraction of the time.

Total lack of persistence in the fall grazed plots indicated that deferment may have been essential to survival. This deferment benefit may not be limited solely to the fall period, however, since this species maintained steady growth through the cold season up to frost kills. Periodic rests throughout the season to maintain adequate root systems may be a possible alternative.

Factors Affecting Persistence

The second objective of this work was to address the question of why individual species survived or failed to persist under the rigors of the field trial. There were many factors which were observed or documented in this study to affect persistence of established plants. These generally fall under the categories of climate, microenvironment and management.

Climatic Adaptation

Despite previous studies which showed these legumes to be adapted to local climatic conditions, some proved less capable of tolerating local stresses than others. Climate could be considered the prime factor in some of these cases by the fact that species reacted differently in different years. *Alysicarpus vaginalis*, with its good stands in May of 1988 and its near disappearance by May 1989 after a dry spring (137 mm from January to May compared to a 30-yr average of 356 mm), was a prime example.

Moisture Stress

All entries, once established, appeared to be tolerant of periodic summer flooding. Florida flatwoods, due to spodic horizons near the soil surface, are particularly prone to this problem. Greenhouse studies are needed, however, to determine exactly what levels and durations each species is capable of enduring since this stress may have contributed to the steady decline most species suffered, especially in combination with other factors. The work done by Quesenberry et al. (1982), for example, showed that differences in water-logging tolerance of Aeschynomene americana was much higher than that of Desmodium heterocarpon.

Periodic droughts, especially prominent in Florida springs, may have been another factor in the decline of certain entries. Species dependent on seed for propagation appeared to be especially affected. Alysicarpus vaginalis and Desmodium heterocarpon, although capable of perennation and plant enlargement, were unable to increase individual plant numbers after 1987 despite heavy seed production in some plots. Seedlings of the latter as well as Macroptilium lathyroides, were observed in low, moist areas outside plots, however, in May 1989. These may have been carried on animal hair or in faeces.

Macroptilium lathyroides and Aeschynomene americana also were affected by lack of moisture at critical periods. These entries are especially vulnerable to spring droughts in which new seedlings were often observed in wilted or dead condition. When this occurs, an entire season's crop may be lost and, more importantly in the long run, a year's seed production may fail. Aeschynomene americana may be less susceptible to this phenomena once soil seed reserves are established from several good growing years. Since Macroptilium lathyroides does not exhibit strong hardseededness, stands are especially susceptible to permanent disappearance after only one dry year. Certainly at establishment, but perhaps also in subsequent springs, moisture was a factor in the lack of permanence in these two species.

The deeper rooted perennials appeared to be less affected by spring drought stress. This was visible in the survival, if somewhat reduced, of deep taprooted Desmanthus virgatus after the spring of 1989. Galactia elliottii was the prime example of this characteristic with its deep and extensive root system. This depth may have contributed significantly to the apparent immunity to low rainfall this species exhibited in the field study and throughout its native range at Ona AREC.

Not all perennials appear to be immune to periodic drought, however. The pot study indicated that perennials such as Desmodium heterocarpon invested in seed production rather than roots when not clipped in the fall. This gives support to the hypothesis that both the heavy seed producing perennials (D. heterocarpon and Alysicarpus vaginalis) in the field essentially disappeared after spring 1989 due to limited root systems. These populations may, however, be able to regenerate if sufficient seed numbers remained ungerminated after the early spring rains of that year.

Temperature Stress

None of the entries appeared to react negatively to high summer temperatures when moisture was not limiting.

All entries, however, had herbage damage from frost and above-ground destruction from freezes. *Desmanthus virgatus* was the only entry observed to lose individual plants completely due to low temperatures. This most often occurred in the ungrazed control plots with very tall plants. Shading of the spring regrowth by heavy neighboring vegetation, both dead and growing, may have been a factor as well.

Galactia elliottii suffered the least frost damage in winter. This was accomplished in two ways. The first was a late fall senescence, documented in November and December during the pot study. During this period *G. elliottii* appeared to translocate nutrients from its leaves as they slowly became chlorotic and finally senescent without apparent disease or nutrient stress. The second method was the retention of some basal leaves and stems in the pasture which did not succumb to cold temperatures, even freezing.

This may have assisted in the early spring regeneration and growth spurt observed every spring in the pasture.

The most important differentiating effect of frosts was time of this stress. Although these did not occur in the 3 yr studied, early fall frosts especially affect seed production. This may have a more drastic affect on the annual Aeschynomene americana then on seeding perennials since individual plants of this last group may seed in subsequent years.

Late frosts were a problem, however. In some perennials which did not respond to cold or daylength by becoming dormant during the winter, growth at moderate levels continued if frosts were not present. Prominent in this group were Desmanthus virgatus and Vigna adenantha. The latter especially resprouted quickly after frosts or freezes. During the early months of 1989 this characteristic may have depleted root energy reserves for these entries. A frost in late December 1988 was followed by seven unseasonably warm, frost-free weeks in which plants of these two species regenerated almost completely. On 26 February freezing temperatures again destroyed above-ground herbage. This, in combination with low rainfall, may have contributed to the decreased survival of plants in all treatments for these two species.

Microenvironment

One of the least understood factors in individual plant survival in the pasture is the microenvironment in which it exists. This can influence the effect of other stresses as well as cause its own. The most important factor under this category is not the microenvironment itself but the individual species's adaptation to that environment.

For example, normally decumbent entries such as *Desmodium heterocarpon* and *Alysicarpus vaginalis* had an advantage in the treatments where grasses and weeds were grazed low. In these plots *Panicum* spp. and *Paspalum notatum* became the dominant grasses. This allowed individual plants to grow and set seed on prostrate branches which cattle could not easily damage. In situations where associated plants were allowed to grow taller, such as the fall deferred plots, these species were forced to grow more upright in order to reach upper canopy sunlight and thereby lost their relative advantage over other entries. In the ungrazed plots where accompanying grasses and weeds were especially dense as well as tall, these entries lost all competitive advantage as born out by the superior relative survival of more upright species. Inability of seedlings to penetrate the dense canopies precluded regeneration from this source despite good seed production.

The reverse was the case for the upright Aeschynomene americana, Macroptilium lathyroides and Desmanthus virgatus. Where accompanying grass and weed species were grazed down to expose new growth or setting seed, these entries soon disappeared. There appeared to be a limit, in terms of height, to the protection offered by accompanying grasses. Desmanthus virgatus had a measurable advantage in the ungrazed control since plants there, once established, could regenerate quickly from stored nutrients in the fall before neighboring grasses dominated the mid-canopy. Annuals could not respond in the same way. The other two entries, dependent more on seed regeneration, soon disappeared from the ungrazed control plots at least in part because they could not maintain viable plant populations year to year through seedling regeneration. The mat of dead and regenerating plant material was simply too dense for light penetration and seedling emergence.

The twining species, Vigna adenantha and Galactia elliottii, once mature, were not hampered by dense grass and weed competition. As long as the individual plants were well established they had no difficulty climbing up their neighbors to reach the upper canopies. Their tendency to intertwine with unpalatable upright weeds and barbed wire served as additional protection in the fall deferred plots. When allowed a respite from grazing, these surviving pockets, especially in the case of *Vigna adenantha*, regenerated to cover larger areas.

These two entries also appeared to regenerate quickly in the spring which also guaranteed that they would not lose their canopy advantage. *Vigna adenantha* in some plots overwhelmed its accompanying grasses and weeds completely.

There may also have been differences in the species' competitiveness with associated grasses and broadleaf plants for moisture and nutrients. This competition, occurring below-ground, was more difficult to observe and compare to the above-ground performance.

Management Factors

Animal effects on the species affected persistence in the field trial. This influence resulted from direct legume harvest and trampling as well as grazing of surrounding non-legume competition.

Direct influences

All entries, according to the height study conducted over the entire grazing season of 1987, were grazed by the animals in the pasture. Wildlife also specifically sought out legumes within grass canopies, preferring *Aeschynomene americana*, *Macroptilium lathyroides* and *Desmanthus virgatus*.

Some of the entries, where sparse and mixed with grasses, may have been grazed by the cattle simply as part of the canopy. Strong rejection, at least, may be ruled out even if preference cannot be safely assumed. Those individual plants which survived grazing must, therefore, of necessity have possessed some mode of defoliation tolerance.

Vigna adenantha throughout the growing season, and perhaps Galactia elliottii in the early spring before cattle were added, overcame defoliation to a degree by vigorous regrowth. Vigna adenantha, especially, was capable of rapid regeneration when allowed a fall deferment.

Aeschynomene americana, Macroptilium lathyroides and Desmanthus virgatus withstood grazing, where already established and developed, through unpalatable stemy growth for at least that season. This grazing deterrent also served these palatable entries as protection from browsing wildlife. The high stem to leaf ratio in the pot study confirmed this trait for Desmathus virgatus, lowering plant nitrogen and presumably acceptability as well.

Desmodium heterocarpon and Alysicarpus vaginalis both persisted in the spring/summer/fall as well as the fall deferred plots by adopting a decumbent growth habit. Decreased plant height during 1987, combined with high persistence in that and subsequent years, confirmed that these two entries derived persistence advantages from prostrate growth habits when canopies were opened due to heavy grazing. Cattle were unable to select leaves and new growth on the old stems. Should these species be utilized for smaller ruminants, however, the usefulness of this avoidance mechanism may be more limited.

Root mass and root TNC mass were also affected by management. The clipping trial indicated that herbage loss of all three species studied affected the plants below ground. *Galactia elliottii* herbage production and below-ground mass seemed the least affected by late fall clipping. This was perhaps due to its natural senescence during this period. *Desmodium heterocarpon* was not affected as much as the others, however. Root mass and TNC content were less drastically reduced than was seed production.

There were certainly more factors than those discussed above, both natural and imposed, which contributed to persistence or lack thereof in the plant populations studied. But these, as with those discussed above, only contributed or interacted to contribute to the population dynamics of the field trial. No single factor could be isolated that would determine the demise or survival of individual plants. The basic premise of this study was, however, that grazing management appeared to have tipped the scales in one direction or another for the species studied.

Indirect influences

Legume cropping may not be the only mode by which grazing animals affected legume persistence. Indirect influences may have resulted due to defoliation effects on surrounding grass and weed canopies.

Casual ingestion of legumes as part of a grass sward has already been mentioned as a possible factor. This phenomenon appears unlikely, however, in light of the largely consistent results measured across plots and years.

Also already discussed was the effect of open canopies on increased persistence of the prostrate perennials. Entries which were dependent on seed for regeneration may also have been affected by canopy characteristics. This may have taken the route of greater seed production for plants protected by denser canopies as well as increased seedling survival in more closely cropped plots where moisture and light competition was less severe.

Relationships Between Defoliation and Plant Composition

The data collected in the pot study from *Galactia elliottii*, *Desmodium heterocarpon* and *Desmanthus virgatus* provided most of the answers which are not directly persistence data or field observations.

Weight and TNC content of roots in the unclipped treatments of the pot study indicated that at least two of the species included in the field trial may have benefited from fall deferment in terms of persistence following winter. Galactia elliottii early in the fall and Desmanthus virgatus throughout the fall likely enlarged roots and stored nutrients in the roots. The native subtropical Galactia elliottii may have developed this capacity over years of adaptation to the low winter temperatures of its native range. Although fall-grazed G. elliottii populations were as persistent as deferred plots, decreased seedling vigor of the undeferred areas was apparent. After several years, differences might become more evident in terms of plant survival and propagation. In the case of the more tropical species such as the introduced Desmanthus virgatus, this increased root and root TNC mass may simply be a result of healthier plants with greater photosynthetic area in place up to frost.

The pot study data on Desmodium heterocarpon indicated, however, that not all perennial species in the trial enlarged root systems and root nutrient storage when not defoliated in the autumn. Those plant populations which invest in seed production during this period, especially the annuals, may benefit from deferment more in terms of greater viability and numbers of seed. The May 1988 persistence data on the only true annual in this study, Aeschynomene americana, indicated that seedling regeneration was the same in the two grazed treatments which were both superior to the ungrazed treatment. This should not refute the basic theory, however, since this phenomena was due perhaps more to conditions favoring seedling survival than to larger seed crops the previous year.

CHAPTER SIX

CONCLUSIONS

This work targeted one factor in the management of seven forage legumes with potential for Florida spodosols: persistence. Over the period of three growing seasons and two yearly grazing cycles, these species showed varying degrees of adaptation to local climatic, microenvironmental and animal use conditions which allowed plant population survival in some cases, total disappearance in others. Possible reasons for differences in survival among entries include degree of adaptation to climate and soil, grass and weed association and competition, plant morphology, capacities to store nutrients in root structures and growth cycles. Some conclusions regarding responses of species can be drawn from the information generated.

Aeschynomene americana and *Macroptilium lathyroides*, the two species studied which are dependent solely on seed for long-term propagation and survival, could not be fully evaluated due to establishment problems. In general, however, these species should benefit from fall deferment since seed set occurs primarily at this time. They also require some grazing of associated plants during the spring to open the canopy for the new seedling crop.

Alysicarpus vaginalis and *Desmodium heterocarpon*, the two heavy seed producers with prostrate growth capabilities, displayed good establishment and early survival under the grazing pressure used. Neither was tolerant of spring drought, however. Their potential to develop extensive soil seed reserves may give them the means, especially in view of the hardseededness they possess, to survive droughty periods. Their characteristic upright growth habit under heavy grass competition, while avoiding complete destruction under heavy grazing via decumbent growth, gives them a versatility some of the more persistent entries did not possess.

Desmanthus virgatus and *Vigna adenantha* both showed promise under fall deferred systems but not under fall grazed regimes. Of these two, the viney, node-rooting *V. adenantha* seems the preferred choice since not a single seedling was added to the *Desmanthus virgatus* population by natural regeneration. *Vigna adenantha*, with its quick regenerative capacities has potential where some opportunity for avoidance of total grazing defoliation is provided by associated plants and grazing management. *Vigna adenantha* may be more useful under short-duration grazing where its innate vigor can be utilized effectively.

Galactia elliottii did not appear to benefit from fall deferment in terms of added persistence although spring regrowth vigor was apparently enhanced by deferment. It was the only entry to show a natural population increase (through rhizomes) under control plot conditions after 3 yr. It also maintained the highest plant population survival, over 50%, in both the deferred and the fall grazed plots. Its strong growth in low-fertility situations makes it promising for range reseeding and recovery.

Mechanisms of tolerance to grazing defoliation differed among the legumes evaluated. The two upright species, dependent solely on seed production for persistence, were especially vulnerable to elimination by grazing. The combination of decumbent growth and heavy seed production were mechanisms of persistence under grazing for *Alysicarpus vaginalis* and *Desmodium heterocarpon*. Woody stems associated with heavy basal plant development gave *Desmanthus virgatus* some resistance to grazing while root TNC storage provided energy for regrowth. Rapid regrowth and vegetative propagation, both of which enhanced stand recovery following defoliation, were key aspects to grazing tolerance in *Vigna adenantha*. These were dependent for effectiveness, however, upon escape from defoliation of some rooted herbage. Extensive root development of *Galactia elliottii* was the primary mechanism of grazing tolerance of this species, undoubtedly at some cost to herbage production.

Total non-structural carbohydrate reserves were an important aspect of winter survival of the perennial legumes. Differing strategies, however, were involved in the three species examined. The only native entry, G. elliottii, developed such extensive underground growth under all treatments that only vigor of regrowth and not persistence was affected by fall grazing. Desmanthus virgatus appeared to build up root TNC in the fall and was dependent upon this energy supply for early regrowth although loss of herbage during the winter made the relationship less well defined for this tropical legume. Desmodium heterocarpon, whose root system was also examined under defoliation treatments, did not appear to build up appreciable levels of root mass or TNC under deferment. This entry, as perhaps occurred with the remaining two perennials in the field trial, was vulnerable to energy depletion for plant maintenance during short, intermittent periods of weather favorable for plant growth during extended winter cold or spring dry periods. Soil seed reserve build-up rather than root TNC increase in both D. heterocarpon and Alysicarpus vaginalis appeared to be the primary mechanism for overcoming this deterrent to stand persistence. In Vigna adenantha the primary response observed was rapid growth and replenishment of limited carbohydrate supply rather than investment in root energy storage.

Management constraints and production capabilities differ considerably among legumes adapted to tropical climates. Effective grazing strategies for sustained production of subtropical legumes in Florida pastures will depend, therefore, upon an understanding of the morphology and physiological responses to stress of the individual legumes to be utilized.

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BIOGRAPHICAL SKETCH

Jim (James Pierre Muir) was born in the small Catota Mission Hospital, Angola, two days before Christmas, 1958. As part of a missionary family, he lived in such diverse locales as Grand Rapids, Michigan, Linda-a-Velha, Portugal, and Huambo, Angola. In 1977, he graduated from Rift Valley Academy, a missionary boarding school on the misty slopes of the Rift Valley escarpment, Kenya.

After four nondescript years as a biology major at Wheaton College, Jim fled the boring American midwest in 1981. Perhaps as much for the refreshing, mountainous topography as for the proximity of a certain fellow Wheatonite, Kaycie (Katherine Cecilia Jones), he settled in Montana. A lonely winter snow-bound in the Little Belt Mountains as a cow-poke was followed, predictably, by the summer 1982 wedding to Kaycie.

Jim and Kaycie moved to Gainesville, Florida in 1983 where Jim commenced work on first a M.S. and then a Ph.D. in forage agronomy. Stolen hours on the oyster bars, tidal creeks and expansive grass flats around Deer Island, Gulf of Mexico, kept sanity intact as classes, library searches, field work and computer hacking made a tropical forage management "expert" out of Jim.

Those who have children of their own know the joy and long, sleepless nights which followed the addition of Peter Neilson Muir to the clan in 1987.

As a precursor to future career goals, graduate work was interrupted in 1988 for a year's Fulbright visit to Mozambique. Jim's driving force in his educational endeavors has been, and still is, a desire to return to his native Planalto do Bié to work with cattle production in Africa.

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.

William D. Pitman, Chairman
Associate Professor of Agronomy

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Kenneth H. Quesenberry, Cochairman
Professor of Agronomy

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Loy V. Crowder
Research Scientist, 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.

George W. Tanner
Associate Professor of Forest Resources and Conservation

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.

Joseph H. Conrad
Professor of Animal Science

This dissertation was submitted to the Graduate Faculty of the College of Agriculture and to the Graduate School and was accepted as a partial fulfillment of the requirements for the degree of Doctor of Philosophy.

August 1989

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