Responses of *Desmanthus virgatus*, *Desmodium heterocarpon*, and *Galactia elliottii* to defoliation

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Abstract

Effects of clipping during autumn every 2 weeks for either three and six clipping cycles were compared to an unclipped control. Autumn herbage production of *D. virgatus* and *D. heterocarpon* was reduced by clipping, but that of *G. elliottii* was not. Root mass and non-structural carbohydrate concentration of roots and stem bases of *D. virgatus* and *G. elliotii* were reduced by clipping, while root mass of *D. heterocarpon* was unaffected by clipping. Root and stem-base carbohydrate accumulation of *D. heterocarpon* was greater for clipped plants than for the unclipped control.

Subsequent spring regrowth was assessed 16 weeks after a winter defoliation. Despite differences in root and stem-base carbohydrate accumulation at the end of autumn ranging from 9.8% for the *D. heterocarpon* autumn control plants to 33.9% for the *G. elliottii* autumn control plants, each of the three species produced similar spring yield responses to winter defoliation following the differential autumn treatments. Winter defoliation reduced regrowth only of plants which had not previously been clipped. Despite lack of effects of autumn clipping treatments on spring regrowth of individual species, spring herbage production among species was correlated with carbohydrate levels at the end of autumn.

Resumen

Los efectos de la defoliación cada dos semanas en el otoño durante tres y seis ciclos de corte fueron comparados con un control sin defoliar. La producción de D. virgatus *y* D. heterocarpon *fue reducida con la defoliación, pero no así la producción de* G. elliottii. *La masa de raíz y la concentración de carbohidratos no estructurales de las raíces y de la base del tallo de* D. virgatus *y* G. elliottii *fueron reducidas con la defoliación, mientras que la masa de raíz de* D. heterocarpon *no fue afectada por la defoliación. La acumulación de carbohidratos de la raíz y de la base del tallo de* D. heterocarpon *fue mayor en las plantas defoliadas que en las no defoliadas.*

El sub-siguiente rebrote de primavera fue evaluado a las 16 semanas después de la defoliación efectuada en el invierno. A pesar de las diferencias en la acumulación de carbohidratos en la raíz y en la base del tallo al final del otoño, las cuales tuvieron un rango de 9.8% para las plantas control de otoño D. heterocarpon *a 33.9% para las plantas control de otoño* G. elliottii, *cada una de las tres especies produjeron un rendimiento similar en primavera como respuesta a la defoliación realizada en el invierno posterior al tratamiento diferencial aplicado en el otoño. La defoliación en el invierno redujo el rebrote únicamente de aquellas plantas que no fueron previamente defoliadas. A pesar que los tratamientos de defoliación de otoño no tuvieron efecto en el rebrote de las plantas individuales en la primavera, el rendimiento entre las especies en la primavera fue correlacionado con los niveles de carbohidratos registrados al final del otoño.*

Introduction

Jones and Mott (1980) have suggested three pathways to persistence of pasture legumes: (*i*) recruitment, (*ii*) short-term perennation plus recruitment, and (*iii*) long-lived individual plants. Pastures can be managed to enhance each plant strategy (Jones and Carter 1989; Curll and Jones 1989). Curll and Jones (1989) emphasized that an understanding of growth of individual species as

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affected by seasonal conditions and grazing will enhance the probability of developing improved pasture management practices.

Three such seasonal conditions exert critical stress on tropical legumes in peninsular Florida. Summer waterlogging limits the range of species, but adapted species are available. Winter frosts and a dry spring season combine to further limit persistence of legume stands. Effects of these stress factors have been described by Ludlow (1980). If legume stands are to persist in peninsular Florida, then consideration must be given to developing management strategies which allow them to avoid the damaging combination of winter frost and spring drought.

The introduced pasture plant, *Desmodium heterocarpon* cv. Florida, persists both by plant perennation and seedling recruitment. Seed production is excellent (Kretschmer *et al.* 1979), but seedling vigour is not good (Pitman 1986). Both seedlings and mature plants are susceptible to severe spring drought (Muir and Pitman 1991). *Galactia elliottii* is a native legume which is well adapted to the environmental conditions but apparently is not tolerant of repeated defoliation (Muir *et al.* 1990). This species persists primarily through survival of individual plants and vegetative propagation. *Desmanthus virgatus* is a shrub legume which has shown potential in the area because of the ability of individual plants to persist and produce good early spring growth. Plant recruitment has not been effective for *D. virgatus* in bahiagrass pastures. Thus these three legumes employ distinct means of stand survival (seedling recruitment of *D. heterocarpon*, vegetative propagation of *G. elliottii*, and individual plant longevity alone of *D. virgatus*) even though perennation of individual plants is important for all three.

Evaluations of persistence of numerous perennial tropical forage legumes under grazing have revealed that stand loss on Florida Spodosol soils is often associated with failure to survive and regrow following winter frost and spring drought (Pitman and Kretschmer 1984; Pitman *et al.* 1988). Many of the native legumes in the region are characterized by high proportions of belowground biomass including distinct tuberous storage organs, similar to those of the savanna species of *Galactia* in South America described by Schultze-Kraft and Giacometti (1979). The ability to accumulate carbohydrates could provide an effective means of surviving the adverse spring environment.

If management strategies during autumn and winter could be devised to enhance spring survival, then the reliability of legume performance could be improved. Thus, carbohydrate levels and regrowth of individual potted plants of these three species were evaluated in response to defoliation treatments to determine possible management strategies to enhance survival during this period.

Materials and methods

Desmanthus virgatus, Desmodium heterocarpon, and *Galactia elliottii* were grown in pots and subjected to various autumn and winter defoliation treatments. Seedlings of the three legumes were transplanted to pots each containing 1 kg of the top 20 cm of Immokalee fine sand (sandy, silicious, hyperthermic Arenic Haplaquod) soil. The experiment was conducted under a transparent fibreglass roof with open sides.

Autumn defoliation

Defoliation treatments were: (*i*) unclipped; (*ii*) early clipping, three clippings at 2-week intervals; and (*iii*) extended clipping, six clippings at 2-week intervals. The experimental design was a randomized complete block design with four replications with treatments consisting of a factorial combination of the three species and the three defoliation treatments. Each treatment combination consisted of 16 plants with one plant per pot giving a total of 576 plants. Plants were assigned to blocks by plant height. The defoliation height was one-half of the average height for each species in each block. These were 23, 22, 18, and 12 cm for *D. virgatus*; 16, 11, 9, and 9 cm for *D. heterocarpon*; and 17, 17, 12, and 9 cm for *G. elliottii*. Defoliation treatments commenced on October 15, 1987.

At each defoliation, harvested material was separated into leaf, stem, and flowers and pods, dried at 72 °C for 48 h, and weighed. Dried samples from all clipping dates were composited to provide one sample of each plant fraction from each pot.

In early winter (early January), half of the plants in each treatment unit were clipped at a 3-cm height above the soil surface, separated into leaf, stem and flowers and pods, dried, weighed, and composited with previous samples from each pot. Roots and stem bases of these plants were washed free of soil, dried at 72 °C for 48 h and prepared for total non-structural carbohydrate

(TNC) analysis. Plants in the remaining eight pots per experimental unit were left intact for evaluation of spring regrowth.

Herbage samples were ground to pass a 1-mm screen and analyzed for total N by an autoanalyzer with aluminum block digestion as described by Gallaher *et al.* (1975). Sample weight was 0.25 g, and the 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). Analysis for TNC was by an enzymatic extraction procedure, involving the colorimetric approach described by Nelson (1944) and the copper-reduction methods of Somogyi (1945), adapted from Smith (1981).

Winter defoliation

Two additional treatments were applied to the remaining plants in each of the above treatment units in early January: (*i*) no further defoliation, and (*ii*) clipping to a 3-cm height (winter defoliation). The experimental design was a strip plot (Gomez and Gomez 1984) with autumn defoliation treatments as the main plots and the winter defoliation treatments as sub-plots. After 16 weeks (May 1988) all plants were harvested to a 3-cm stubble height. Both harvested herbage and roots were recovered, dried, and weighed.

Results

Autumn defoliation

Herbage production of individual plants of both *D. virgatus* and *D. heterocarpon* during the 12-wk autumn period was greatest in the unclipped treatment (Table 1). Clipping treatments did not affect herbage production of *G. elliottii*, which naturally senesces during autumn. Herbage production of individual *D. virgatus* and *D. heterocarpon* plants was similar under both clipped treatments, while *G. elliottii* produced substantially less herbage in all treatments than did the other two species. *D. virgatus* produced a leafier herbage than did *G. elliottii*, with an intermediate level in most treatments for *D. heterocarpon* (Table 1), which also senesces following seed maturity in late autumn. The low leaf:stem ratio of *G. elliottii* reflects leaf senescence during the clipping period. In both *G. elliottii* and *D. heterocarpon*, clipping treatments caused an approximate doubling of the leaf:stem ratio, suggesting a delay in leaf senescence. By the end of autumn, *D. heterocarpon* and *G. elliottii* plants in the extended autumn clipping treatment retained substantially more leaves than did plants in the other two treatments.

Reproductive development was reduced in both *D. heterocarpon* and *D. virgatus* by clipping (Table 1); however, even the unclipped *D. virgatus* plants produced very little reproductive growth, probably due to immaturity of these plants. Herbage N levels were low reflecting the low soil fertility and limited N fixation during the autumn season, even though plants were nodulated.

Root production contrasted with herbage production (Table 1). The greatest root production was by *G. elliottii* in the unclipped treatment. Quantity of root mass was similar to that of herbage mass for *D. virgatus* in each treatment; root mass of *D. heterocarpon* was slightly greater than herbage mass in each treatment; and root mass of *G. elliottii* was substantially greater than herbage mass in each treatment. Both clipping treatments reduced root production from that of the controls for *D. virgatus* and *G. elliottii*. Root mass of *D. heterocarpon* was not affected by clipping treatments, which may contribute to the grazing tolerance of this legume. Both *G. elliottii* and *D. virgatus* had high root and crown TNC concentrations, which were reduced by clipping (Table 1). *D. heterocarpon* had much lower TNC levels, and they were higher in clipped plants than in unclipped plants. Lower root hot-water-soluble sugars with less-frequent clipping (16 wk vs. 8 and 4 wk) have been reported previously for *Macroptilium atropurpureum* cv. Siratro (Jones 1974).

Winter defoliation

Main effects of the initial autumn clipping treatments and plant species for each winter defoliation treatment are presented in Table 2, since there were no species by autumn clipping treatment interactions. Winter defoliation reduced spring regrowth and root mass compared with that of the respective control only for plants which had not been clipped during autumn. Adverse effects of a single, severe late-season defoliation have been reported previously for *Stylosanthes humilis* (Fisher 1973; Robertson *et al.* 1976). Spring regrowth of plants not subjected to winter defoliation was adversely affected by early, but not by extended, autumn clipping.

Table 1. Responses of individual plants of *Desmanthus virgatus, Desmodium heterocarpon*, and *Galactia elliottii* to successive autumn defoliation treatments commenced in October 1987 and evaluated in January 1988

	Autumn defoliation treatment		
Species	Early	Extended	Not clipped
Herbage mass (g)			
D. virgatus	2.5 bA[1]	2.4 bA	4.0 aA
D. heterocarpon	2.3 bA	2.3 bA	2.9 aB
G. elliottii	0.7 aB	0.6 aB	0.6 aC
Leaf-stem ratio			
D. virgatus	1.1 aA	1.2 aA	1.2 aA
D. heterocarpon	0.9 aA	0.9 aB	0.4 bB
G. elliottii	0.4 aB	0.4 abC	0.2 bC
Flower and pod mass (g)			
D. virgatus	0.0 bB	0.0 bB	0.2 aB
D. heterocarpon	0.4 bA	0.5 bA	1.0 aA
G. elliottii	0.0 aB	0.0 aB	0.0 aC
Herbage nitrogen (%)			
D. virgatus	1.9 bB	2.1 aA	1.2 cB
D. heterocarpon	2.1 aA	2.1 aA	1.8 bA
G. elliottii	1.9 aB	1.9 aB	1.3 bB
Root mass (g)			
D. virgatus	2.6 bB	2.4 bA	4.8 aB
D. heterocarpon	3.8 aA	3.1 aA	3.4 aC
G. elliottii	2.9 bB	2.8 bA	5.7 aA
Root and crown total non-structural carbohydrate (%)			
D. virgatus	22.1 bB	23.0 abB	25.3 aB
D. heterocarpon	12.0 aC	12.1 aC	9.8 bC
G. elliottii	25.7 bA	25.5 bA	33.7 aA

[1] Lower case letters refer to differences within each row and upper case letters to differences within each response variable in each column according to Duncan's Multiple Range Test ($P<0.05$).

D. virgatus plants which had not been subjected to winter defoliation produced more spring herbage than either the other species or winter-defoliated *D. virgatus* plants. They also had greater root mass than the other species (Table 2). The apparent asset of large quantities of root and stem-base TNC storage of *G. elliottii* did not produce an advantage in spring regrowth over the other species when not subjected to winter defoliation. Spring herbage mass of *G. elliottii* was greater than that of the other species when subjected to winter defoliation, and winter defoliation failed to adversely affect its spring regrowth. Spring herbage and root masses of winter-defoliated *D. heterocarpon* plants were substantially lower than those of the other species and of undefoliated *D. heterocarpon* plants.

Table 2. Effects of successive autumn defoliation treatments and winter defoliation on spring regrowth of individual plants of *Desmanthus virgatus, Desmodium heterocarpon*, and *Galactia elliottii*

Autumn defoliation treatment	Winter defoliation treatment	
	Clipped	Not clipped
Herbage mass (g)		
Early	1.1 aAB[1]	1.3 aB
Extended	1.3 aA	1.5 aAB
Not clipped	0.9 bB	1.8 aA
Root mass (g)		
Early	1.6 aA	1.5 aB
Extended	1.5 aA	1.7 aAB
Not clipped	1.3 bA	2.1 aA
Species		
Herbage mass (g)		
D. virgatus	1.3 bB	2.1 aA
D. heterocarpon	0.3 bC	1.2 aB
G. elliottii	1.7 aA	1.3 aB
Root mass (g)		
D. virgatus	1.8 aA	2.2 aA
D. heterocarpon	0.7 bB	1.5 aB
G. elliottii	1.9 aA	1.6 aB

[1] Lower case letters refer to differences within each row and upper case letters to differences within each response variable in each column according to Duncan's Multiple Range Test ($P<0.05$).

Discussion

Lower root masses and TNC concentrations of *D. virgatus* and *G. elliottii* plants subjected to autumn defoliation indicate that plant vigour was reduced by defoliation. However, these differences did not affect subsequent spring regrowth. All plants may have been above the critical TNC level needed for survival and regrowth. A recent field plot experiment on a Florida phosphatic clay site produced a range in root and stem TNC levels in *D. virgatus* plants clipped at various frequencies to a 5-cm height. Plants at a 2-week harvest frequency had less than 2% root TNC and failed to perennate, while those at the 12-week harvest frequency had greater than 7% root TNC and produced vigorous, early spring regrowth (W. Trujillo and W. D. Pitman, unpublished data). Grazing management strategies involving autumn deferment from grazing may be effective in restoring vigour of depleted *D. virgatus* and *G. elliottii* plants.

The responses in root mass and TNC concentration of *D. heterocarpon* to autumn defoliation contrasted with those of the other two species. Thus, while autumn deferment may enhance seed production of *D. heterocarpon*, vigour of individual plants may actually be decreased by deferment from grazing as developing seed become a priority sink for autumn photosynthate. Autumn grazing management of this species must balance the need for annual replenishment of soil seed reserves, enhanced by reduced grazing pressure, with maintenance of individual plant vigour, which can be reduced by high seed production.

Autumn defoliation enhanced leaf retention of *D. heterocarpon* and *G. elliottii*, indicating that winter photosynthesis may contribute substantially to maintenance of these plants when not subjected to winter defoliation. Within individual legumes, residual leaf area rather than root and stem-base TNC appeared to provide the critical control of spring growth. This concurs with the conclusions of Harris (1978). In comparisons among legume species, spring herbage production following winter defoliation was in the same order as total TNC accumulation. While TNC levels of these legumes may not fluctuate enough to substantially affect herbage production of individual plants under most management situations, the ability to accumulate TNC in autumn may be a useful indicator of early spring herbage production potential among species or ecotypes and be of value in germplasm screening.

The contrasting effects of autumn defoliation on these legumes illustrate that a single pasture management approach cannot be applied across species. Vigour of individual *D. virgatus* and *G. elliottii* plants, which could contribute to survival under extended stress, should be enhanced by autumn deferment from grazing. In contrast, extended grazing during autumn may be beneficial to *D. heterocarpon*, at the expense of seed production.

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