

Effect of defoliation frequencies on the dry matter yield and nutrient content of two *Centrosema* species.

J. Faría-Mármora, D. E. Morillo² and Z. Chirinos¹

La Universidad del Zulia, Departamento de Zootecnia, Postgrado en Producción Animal,
Apartado Postal 526. Maracaibo, Venezuela

ABSTRACT: A trial was conducted to study the effect of three defoliation frequencies, at $F_1=4$, $F_2=6$ and $F_3=8$ - wk intervals, on dry matter yield (DMY), crude protein (CP) and mineral composition of *Centrosema macrocarpum* (Cm) and *Centrosema pubescens* (Cp). A split-plot experimental design with species (main plots), defoliation frequencies (subplots) and three replications was used. Samples for each defoliation frequency, corresponding to rainy (RS) and dry periods (DS), were analyzed for CP and calcium (Ca), phosphorus (P), magnesium (Mg), potassium (K), copper (Cu), iron (Fe), and manganese (Mn) concentrations. DMY of Cm ($4.4 \text{ t ha}^{-1}\text{year}^{-1}$) was higher ($P<0.05$) than of Cp ($1.5 \text{ t ha}^{-1}\text{year}^{-1}$). DMY increased ($P<0.05$) with increasing cutting interval ($F_1=2.4$, $F_2=2.5$ and $F_3=3.6 \text{ t ha}^{-1}$), whereas CP, ash, and most mineral concentrations were not affected ($P>0.05$). Only Ca declined ($P<0.05$) with increasing plant maturity. Ca and P concentrations were affected by season ($P<0.05$). In Cm, Ca concentrations during RS (1.27%) were lower than in the DS (1.55%), whereas in Cp, P concentrations were higher ($P<0.05$) in RS (0.25%) than in DS (0.21%). In both species, Fe, Cu and Mn concentrations decreased ($P<0.05$) during RS. Other elements were not affected ($P>0.05$) by season. Mineral concentrations of the two species were adequate to cover grazing ruminant nutritional requirements with the possible exception of P (0.21%). Forage P concentrations may have been influenced by the low soil P content. Ash and Cu concentrations were lower ($P<0.005$) in Cm than Cp but CP and mineral composition did not differ between species.

Keys words: Centrosema, defoliation frequencies, yield, crude protein, mineral composition.

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Efecto de la frecuencia de defoliación en la producción de materia seca y contenido de nutrientes de dos especies de *Centrosema*

RESUMEN: Se estudió el efecto de tres frecuencias de defoliación (F) a intervalos de $F_1=4$, $F_2=6$ y $F_3=8$ semanas sobre la producción de materia seca (PMS), proteína bruta (PB), y composición mineral de *Centrosema macrocarpum* (Cm) y *Centrosema pubescens* (Cp). Se utilizó un diseño de bloques al azar en parcelas divididas y tres repeticiones, con especies (parcela principal), y las frecuencias de defoliación (parcela dividida). Se analizaron muestras de cada F para PB, Calcio (Ca), fósforo (P), magnesio (Mg), potasio (K), cobre (Cu), hierro (Fe), y manganeso (Mn) durante las épocas seca (ES) y lluviosa (ELL). La PMS fue mayor ($P<0.05$) para Cm ($4.4 \text{ t ha}^{-1} \text{ año}^{-1}$) que Cp ($1.5 \text{ t ha}^{-1} \text{ año}^{-1}$). El incremento de F aumentó la PMS ($F_1=2.4$, $F_2=2.5$ y $F_3=3.6 \text{ t ha}^{-1}$), sin afectar ($P>0.05$) la PB, ceniza y la mayoría de los minerales; solo Ca disminuyó ($P<0.05$) con la madurez. En Cm el Ca fue menor ($P<0.05$) durante ELL (1.27%) que en ES (1.55%), mientras que en Cp el P (0.25%) fue mayor ($P<0.05$) durante ELL que en ES (0.21%). En ambas especies el Fe, Cu y Mn disminuyeron ($P<0.05$) durante ELL. Otros elementos no se afectaron ($P>0.05$) por la época del año. Los minerales de ambas especies resultaron adecuados para rumiantes a pastoreo con la posible excepción del P (0.21%) posiblemente por el bajo P del suelo. La ceniza y el Cu fueron menores ($P<0.05$) en Cm que en Cp, pero la PB y los restantes minerales no difirieron entre especies.

Palabras claves: Centrosema, frecuencia de defoliación, proteína bruta, composición mineral

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²Instituto Nacional de Investigaciones Agrícolas (INIA), Maracaibo, Venezuela.

Introduction

Centrosema is a legume genus native to Central and South America, and includes species with potential adaptation to diverse habitats such as the dry and high-altitudes tropics, subtropics, poorly drained and/or seasonally flooded conditions, and acid, low-fertility soils (Schultze-Kraft *et al.*, 1990). Studies have focused on the well-drained isohyperthermic savannas («Llanos» ecosystem) and tropical forest ecosystem of Colombia and Venezuela, where several *Centrosema* species such as *C. macrocarpum* and *C. pubescens* have shown considerable forage potential (Grof *et al.*, 1997).

Centrosema macrocarpum is a promising legume for a wide range of ecological conditions throughout the tropics. Its excellent forage yield, drought tolerance and high nutritive value are considered of particular importance (Miles and Lapointe, 1992).

Centrosema pubescens is the only well-known *Centrosema* species that has been widely evaluated, is available commercially, and has the largest number of collected germplasm accessions. Some systematic screening has been carried out on noncommercial lines of *C. pubescens*. Regional reports (CIAT, 1990) show to a varying degree that these accessions have potential for acid soil sites in humid tropical environments, but not in savanna ecosystems. Several studies have been conducted in different ecological areas of Venezuela to evaluate the dry matter yield (DMY) of several accessions of *Centrosema pubescens* (Faría-Mármol *et al.*, 1997a; Grof *et al.*, 1997; Pirela-León *et al.*, 1997). Among the highest yielding accessions, CIAT (Centro Internacional de Agricultura Tropical) No. 15160, has shown the best performance.

Further research on *Centrosema macrocarpum* and *Centrosema pubescens* is needed to assess their forage yield and nutrient concentration in the local environment. The objective of this study was to evaluate the effect of three defoliation frequencies on DMY, crude protein (CP) concentration and mineral composition of *Centrosema macrocarpum* and *Centrosema pubescens* during two seasons in a wet/dry region of Venezuela.

Materials and Methods

The experiment was conducted on a farm located in Zulia State, western region of Venezuela (10° 32' 32" N and 72° 12' 30" W), with climate and vegetation corresponding to a tropical dry forest. Mean annual rainfall is 960 mm, distributed in a dry (four months) and a rainy (eight months) season. Total precipitation during the experiment (336 days) was 730 mm,

distributed between one «dry» (90 mm, 156 days) and one «rainy» (640mm, 180 days) period. Soil was a sandy-loam Typic Haplustalf with pH 5.2 and 2.68% organic matter. Average soil macroelement analysis (mg/kg) was: phosphorus (P), 8; calcium (Ca), 100; potassium (K), 60 and magnesium (Mg), 324.

Two species of *Centrosema*, *C. macrocarpum* CIAT 5713 and *C. pubescens* CIAT 15160 were evaluated in a split-plot experimental design containing three replications, with species as the main plots (36m²) and defoliation frequencies (4, 6, and 8 week-intervals) as the subplots (12 m²).

The available forage 10 cm above the ground in the central 2 x 2-m area of each plot was cut using hand shears, weighed, and a sample (ca. 500 g) consisting of 10 grab sub-samples was taken to determine dry matter concentration at 60 °C for 48 hours, and to estimate DMY.

Dry matter yield was evaluated throughout the whole year. Samples from the first, mid and last cuttings for each frequency in two replications, corresponding to rainy and dry periods, respectively, were used to determine CP concentration by the Kjeldhal (Kjeldhal N x 6.25) procedure (Horwitz, 1982). Sub-samples for macro and microelement analyses were processed following the methods outlined by Fick *et al.* (1979), and P was analyzed by a colorimetric technique (Harris and Popat, 1954). Calcium, K, Mg, Cu, Fe and Mn concentration were determined by flame atomic absorption spectrophotometry (AAS), (Perkin-Elmer Corp, 1982).

Data were subjected to ANOVA for a split plot design using the General Linear Model procedure of SAS (1992). If appropriate, means were compared using Duncan's Multiple Range Test as described by Steel and Torrie (1992).

Results and Discussion

Mean dry matter yields of *C. macrocarpum* and *C. pubescens* as affected by the frequency of defoliation and species are presented in Table 1. The interaction species x frequencies was not significant ($P>0.05$) for DMY. DMY increased ($P<0.05$) when the cutting interval was increased from 4 to 8 weeks. Dry matter production was higher ($P<0.05$) in *C. Macrocarpum* than in *C. pubescens*. These results are similar to those reported in areas with low rainfall and a long dry season (CIAT, 1990; Pérez, 1995). Dry matter yields obtained in this research were comparable to those reported in savanna ecosystems but lower than those found in the humid tropics (CIAT, 1990).

DM yield declined ($P<0.05$) in *C. macrocarpum* (75.9%) and *C. pubescens* (85.3%) during the dry season

Table 1. Mean dry matter yield (kg ha⁻¹) of two species of *Centrosema* as affected by defoliation frequency during two seasons in a wet/dry tropical region of Venezuela^{1,2}

Defoliation Frequency (weeks)	<i>C. pubescens</i> Season		<i>C. macrocarpum</i> Season		Overall
	Rainy	Dry	Rainy	Dry	
4	1.141	194	2.380	1.138	2.427 ^b
6	1.425	177	3.168	1.036	2.904 ^{ab}
8	1.495	227	5.057	383	3.579 ^a
Overall	1.352 ^a	200 ^b	3.535 ^a	853 ^b	2.970
SE ³	379	101	379	101	303

¹Least-square means based on 18 observations.²Means in the same column or row within a species followed by different letters are different (P<0.05).³Standard error.

as compared to the wet season. These results are similar to those reported by CIAT (1990), Faría-Mármol (1995) and Faría-Mármol *et al.* (1997a), and can be ascribed to the effect of water deficit on plant growth and development (Buxton and Fales, 1994).

CP, ash and mineral concentrations for *C. macrocarpum* and *C. pubescens* are shown in Table 2. No differences (P>0.05) were detected between species for CP and concentration of most mineral. Only ash and Cu concentrations were lower (P<0.05) in *C. macrocarpum* than in *C. pubescens*. All mean and individual concentrations for the macro and trace elements evaluated in this research were below the suggested maximum tolerable levels for cattle (NRC, 1980; McDowell, 1992).

Mean CP concentrations (22 and 18%) were within the range reported for *Centrosema* spp growing in Ve-

nezuela (Pérez, 1995; Faría-Mármol, 1995; Faría-Mármol *et al.*, 1997b) and other tropical regions (Shultze-Kraft *et al.*, 1990; Lascano *et al.*, 1990). These values are considerably higher than 7%, which is the minimum CP content indicated by Milford and Minson (1965) to avoid a depression in forage voluntary intake by grazing livestock. The mean ash concentration was consistently below 9.5 % in both species.

Mean Ca, K and Mg concentrations, as well as all the individual values, can be regarded as adequate for ruminant livestock when compared to the mineral element requirement (MER) or critical level for deficiency (McDowell, 1992; NRC, 1989, 1996). Conversely, mean P concentrations, with relative deficiencies of 44 and 78% in Cm and Cp, respectively, are inadequate according to the same reference values.

Table 2. Mean crude protein (CP), ash, and mineral concentrations of *Centrosema macrocarpum* and *C. pubescens* in a wet/dry tropical region of Venezuela^{1,4}

Item	Centrosema		Overall	SE ^b	MER ³	Range
	<i>Pubescens</i>	<i>macrocarpum</i>				
CP (%)	21.6	17.9	8.8	0.88	-	-
Ash (%)	8.66 ^a	7.62 ^b	8.41	1.03	-	-
Ca (%)	1.18	1.55	1.36	0.10	0.30	-
P (%)	0.22	0.20	0.21	0.01	0.25	-
Ca:P	5.36	7.52	6.43	1.07	-	-
Mg (%)	0.48	0.51	0.49	0.01	0.18	0.05-0.25
K (%)	1.72	1.58	1.64	0.09	0.60	0.50-0.70
Fe (mg/kg)	238	213	232	40	50	50-100
Cu (mg/kg)	11.9 ^a	8.28 ^b	10.1	1.91	8.0	4.0-10.0
Mn (mg/kg)	151.0	138.0	143.8	15.0	40.0	20-50

¹Least-square means based on 12 observations.²Standard error.³Mineral element requirement or critical level for deficiency.⁴Means in the same row followed by different letters are different (P<0.05).

Mean Ca:P ratios (6.4:1) were within the tolerable range for ruminants (NRC, 1989, 1996). Several investigations (Wise *et al.*, 1963; Ricketts *et al.*, 1970) have demonstrated a significant decrease in growth and feed efficiency of cattle fed dietary Ca:P ratios over 7:1. For both *Centrosema* species, mean Fe and Mn concentrations as well as all the individual values of these elements, are considered adequate according to the MER suggested for ruminants (McDowell, 1992; NRC 1989, 1996). However, differences ($P < 0.05$) between forage species were detected for Cu concentrations. Cu concentrations, which were adequate in *Cp* in relation to the suggested requirement for grazing ruminants, but marginal in *Cm* with 44% of the individual values below the critical level for deficiency.

The effect of defoliation frequencies on nutrient concentrations of *C. macrocarpum* and *C. pubescens* are presented in Table 3. All nutrients evaluated in this study tended to decrease with increasing forage maturity, no differences ($P > 0.05$) among cutting frequencies were observed for ash and most minerals. Only Ca concentrations declined ($P < 0.05$) with increasing plant maturity. The lowest Ca concentration (1.1%) was obtained with the longest cutting interval, probably due to an increase in the proportion of the stem fraction as the forage matures since stems generally contains less Ca than leaves (Minson, 1990). A general declining trend with increasing plant maturity has been reported for Ca, P, K and microelements concentrations by some researchers (Underwood, 1981; Spears, 1994),

whereas Minson (1990) pointed out that except for Cu, which usually follows the general trend, plant age has had conflicting or inconsistent effects on mineral concentrations.

Seasonal means for CP, ash and mineral concentrations of two *Centrosema* species are given in Table 4. Mean PC values were high and similar ($P > 0.05$) for the dry (18.78%) and rainy seasons (20.28%) in both forage species and agree with those reported by Lascano *et al.* (1990) and Faría-Mármol *et al.* (1997b).

Calcium concentration of *C. macrocarpum* was lower ($P < 0.05$) during the rainy season (1.55%) than the dry season (1.27%), whereas no differences ($P > 0.05$) were detected for other macroelement concentrations in that species. Phosphorus was the only macroelement affected ($P < 0.05$) by season in *C. pubescens*, with a higher value during the rainy season (0.27%) than the dry season (0.22%).

Mean Fe, Cu, and Mn concentrations declined ($P < 0.05$) during the rainy season. Except for Cu, trace mineral concentrations were regarded as adequate in both seasons and in both species. Copper concentration of *C. macrocarpum* was below the recommended level for ruminants during the dry season. Kabaija and Smith, 1989 reported an unexplained increase in the concentration of Mn, Fe, Zn and Cu during the dry season. Seasonal changes in microelement concentrations of forage have been reported, but there is not consistency in the direction of the changes (Minson, 1990).

Table 3. Mean crude protein (CP), ash, and mineral concentrations of *Centrosema macrocarpum* and *C. pubescens* as affected by the frequency of defoliation^{1,4}

Item	Defoliation frequency (weeks)			Overall	SE ²	MER ³	
	4	6	8				
CP (%)	20.1	19.8	19.3	19.8	0.95	-	-
Ash (%)	8.5	8.1	8.0	8.40	0.24	-	-
Ca (%)	1.3 ^a	1.2 ^{ab}	1.1 ^b	1.22	0.03	0.3	-
P (%)	0.25	0.23	0.22	0.23	0.01	0.25	-
Ca:P	5.44	5.40	5.24	5.36	0.18	-	-
Mg (%)	0.51	0.51	0.47	0.49	0.01	0.18	0.05-0.25
K (%)	1.74	1.61	1.59	1.64	0.04	0.60	0.50-0.70
Fe (mg/kg)	206	178	142	175	26.0	50.0	50-100
Cu (mg/kg)	2	10	8	10.1	0.32	8.0	4.0-10.0
Mn (mg/kg)	147	146	141	144	3.55	40.0	20-50

¹Least-square means based on 18 observations.

²Standard error.

³Mineral element requirement or critical level for deficiency.

⁴Means in the same row followed by different letters are different ($P < 0.05$).

Table 4. Mean crude protein (CP), ash and mineral concentrations of two *Centrosema* species in a wet/dry region of Venezuela, as affected by season^{1,3}.

Item	C. pubescens		C. macrocarpum		Season Overall			
	Season		Season		Rainy Season		Dry Season	
	Rainy	Dry	Rainy	Dry	Mean	SE ²	Mean	SE
CP (%)	22.6	19.8	17.9	17.8	20.3	1.2	18.8	0.69
Ash (%)	7.37	8.13	8.64	8.69	8.0	0.48	8.4	0.23
Ca (%)	1.03	1.18	1.27 ^b	1.55 ^a	1.15 ^b	0.08	1.37 ^a	0.03
P (%)	0.27 ^a	0.22 ^b	0.23	0.21	0.25 ^a	0.02	0.21 ^b	0.01
Ca:P	3.8 ^b	5.4 ^a	5.7	7.5	4.8 ^b	0.03	6.4 ^a	0.26
Mg (%)	0.47	0.48	0.49	0.53	0.49	0.05	0.51	0.01
K (%)	1.74	1.68	1.56	1.62	1.64	0.09	1.64	0.05
Fe (mg/kg)	143 ^b	231 ^a	149 ^b	214 ^a	147 ^b	25.8	214 ^a	11.7
Cu (mg/kg)	10.5 ^b	14.7 ^a	5.8 ^b	13.3 ^a	8.13 ^b	1.9	14.0 ^a	0.81
Mn (mg/kg)	122 ^b	170 ^a	132 ^b	188 ^a	127 ^b	11.2	179 ^a	5.17

¹Least-square means based on 24 observations.²Standard error.³Means in the same row within species followed by different letters are different ($P \leq 0.05$).

Conclusions

Centrosema macrocarpum produced higher DMY than *C. pubescens*, and DMY increased with increasing harvest interval. However, crude protein, ash and most mineral concentrations were not affected by the frequency of defoliation. Only Ca concentrations decreased with increasing plant maturity. Crude protein concentrations and most mineral nutrients were similar between forage species. From the standpoint of ruminant nutrition, P concentrations in both species and Cu concentration in *C. macrocarpum* were deficient. Most mineral concentrations were affected by season, but those changes may not be nutritionally significant. The importance of these deficiencies will depend on the amount and composition of other ingredients of the diet, since these species are usually grown in association with grass species.

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