Season of cutting affects biomass production by coppicing browse species of the Brazilian caatinga

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Abstract

This paper reports the effect of season of cutting on coppice biomass production by 5 tree species common in the semiarid caatinga woodlands of northeast Brazil. Trees were cut early and late in the wet and dry seasons and coppice biomass production was monitored for 2 growing seasons after cutting.

No mortality occurred as a result of cutting in any season. The effect of season of cutting on subsequent coppice production was most pronounced in the first year but differences persisted into the second year. Production by trees cut late in the wet season lagged behind that of trees cut at any other time. This was true for all species except marmeliero (*Croton hemiargyreus* Muell. Arg.) during both years. Pau branco (*Auxemma oncocalyx* Taub.) production was maximized by cutting late in the dry season. Jurema preta (*Mimosa acutistipula* Benth.) and catingueira (*Caesalpinia pyramidalis* Tul.) production was maximized by cutting early in the dry season. The season of cutting does not affect marmeliero stem production. Except for the late wet season, no treatment significantly affected sabiá *Mimosa caesalpinifolia* production. Stem biomass production is affected more by season of cut than is leaf biomass production. The different patterns of response among these species could be the basis of a selective cutting scheme to achieve objectives such as browse and wood production.

Key Words: sprouting, woodland grazing, shrubland grazing

Northeast Brazil is a densely populated agricultural region where many people live at or below subsistance level. Crop and livestock production are mixed and livestock are an important source of food and income. Small ruminants are the most common livestock, accounting for 18 and 92% of the nation's sheep and goat populations, respectively (USAID Unpub. Project Proposal 1980).

Fluctuating forage supplies are a major constraint to livestock production. The native vegetation, known as caatinga, is a complex mix of deciduous woody species with an annual herbaceous understory. During the 6-9 month dry season, forage disappears rapidly as herbaceous plants and fallen tree leaves are either consumed or disintegrate. This annual period of nutritional stress results in low reproductive rates and substantial weight losses (Huss 1976).

Traditionally, the caatinga is cut and burned for either cropland or pasture improvement. Several years after this treatment woody plants reinvade, and the stand is abandoned for up to 20 years. Acceleration of this cycle is thought to account for widespread soil erosion and undesirable changes in vegetation cover and composition. More sustainable brush management techniques are needed to meet producers' needs.

The literature provides numerous examples of brush management techniques adapted to particular objectives (Hardesty 1984). In Brazil we focused on techniques which would be acceptable and affordable by subsistance farmers. Manual control, controlled burning and grazing are already practiced in the region, though the full potential of these techniques is unreported. The ability of most caatinga species to sprout (coppice) has made control difficult. However, complete control of woody vegetation is usually not desirable because the leaves of some woody plants can be a critical source of forage during the dry season (Pfister and Malechek 1986).

Coppice growth is a valuable forage resource. All of the desirable browse species in the caatinga sprout prolifically, and coppice growth of many of the normally unpalatable species is palatable to sheep and goats. In addition, coppice growth remains green for several months after intact trees have shed their leaves. Foresters have managed coppicing trees to achieve various objectives and manipulation of coppice growth may also be useful in managing browse ranges.

Numerous factors have been suggested or demonstrated to influence coppicing including species, ecotype, site, season of treatment, type and frequency of injury, age, diameter and height of the stump, origin and placement of the sprout, stem and root carbohydrate levels, and various growth regulators (Blake 1983). Most of the work on the subject has been with temperate tree species and a few humid tropical species (Walters 1972, Walters and Wick 1973). The range of known coppicing responses is so broad that assumptions about an unstudied species are risky, especially in an unusual environment such as the caatinga.

The season of cutting is one factor that is easily manipulated. It is generally stated that coppicing is maximized by cutting during the dormant season and minimized by cutting during active growth (Smith 1986). Our paper reports on the effect of season of cutting on coppice production of several caatinga species. The objectives were to determine: (1) if season of cutting affects subsequent above-ground biomass production, (2) if cutting at particular times causes stump mortality, (3) if the ratio of leaf to stem biomass is influenced by season of cutting, and (4) if seasonal variation in cutting provides enhanced management opportunities for the caatinga.

Methods

Study Sites

This study was conducted at 2 sites within the state of Ceará. The Sobral site was located at the National Goat Research Center of the national agricultural research organization (EMBRAPA), near the town of Sobral at an elevation of 63 m. The Quixadá site was located at Fazenda Iracema, an experimental farm operated by the state agricultural research organization (EPACE), near Juatama at an elevation of 180 m.

The interior of Ceará is semiarid with rainfall normally concentrated between January and April. This is variable, however, and extended droughts are characteristic. The average annual rainfall for Sobral is 759 mm. During the study (1982–1984), the annual rainfall was 650, 447, and 986 mm, respectively. Average annual rainfall at Quixadá is 873 mm, but it was 710, 275, and 769 mm during the study. The average annual temperature range for the region is 22–26° C, with little daily or seasonal variation (Camargo 1965). Potential evaporation ranges from 1,000–1,500 mm/yr (Camargo 1965, Eiten and Goodland 1979).

Both sites have shallow soils (<.5 m) underlain by a crystalline shield. The dominant soils at the Sobral site are a sandy-gravelly

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lithosol, a non-calcic brown soil with a clay layer, and a eutrophic red-yellow podzol. All are moderately to well drained. Soils at the Quixadá site are lithosols and non-calcic brown soils (Ramos 1981). Both sites have gently rolling topography.

Study sites were located in mature caatinga stands but the nature of the vegetation at the 2 sites varied. The caatinga near Sobral is dominated by pau branco (*Auxemma oncocalyx* Taub.), a species that does not occur in Quixadá. Woody species that dominate the Quixadá site include jurema preta (*Mimosa acutistipula* Benth.), catingueira (*Caesalpinia pyramidalis* Tul.), and sabiá (*Mimosa caesalpinifolia* Benth.). All of these species are common in Sobral, as are marmeliero (*Croton hemiargyreus* Muell. Arg.) and mofumbo (*Combretum leprosum* Mart.). Mororó (*Bauhinia forficata* Link.) occurred more frequently in Sobral, and a variety of species which together composed a small part of the flora at Quixadá did not occur at all in Sobral. There is no comprehensive vegetation classification for this region making ecological interpretations of vegetation largely speculative. Jurema preta dominates disturbed sites but once a canopy is established, it fails to reproduce, becomes decadent, and dies out of the maturing stand. The Quixadá site had considerably more live jurema preta, thus the stand may be somewhat younger than the Sobral stand. Both stands are considered "old" (40–60 years) by longtime residents, and are dense stands (23,000 stems/ha in Quixadá), 6–10 m in height, with closed canopies.

Species Studied

The species studied were sabia, catingueira, marmeliero, pau branco, and jurema preta, all of which are common throughout the region. Sabiá is a small tree, highly preferred for fenceposts and as long-, hot-burning firewood suitable for firing ceramics and other industrial uses. Sabia's foliage is extremely palatable to sheep and goats throughout the year.

Catingueira occurs in several plant associations and in more habitats than any of the other species studied. At both study sites, it was a dominant species in terms of size and frequency. This tree tends to become hollow with age and burns rapidly. Hence, its value for wood or fuel is limited. Catingueira is one of the first trees to produce leaves when seasonal rains begin, and the foliage is eagerly sought by livestock. After a few days the foliage acquires a strong, pungent smell and is ignored by livestock until leaves have dried and fallen at the end of the wet season. This characteristic ensures that catingueira foliage will be available for consumption during the dry season.

Marmeliero is a small tree, rarely exceeding 8 m in height or 10 cm in diameter. It has limited value for construction or firewood and is not normally browsed by livestock. If sufficient rain occurs during the dry season, marmeliero will produce leaves, and livestock will browse it at this time (Pfister and Malechek 1986). This tree tends to form dense stands and is considered an invader, often dominating cleared pastures or disturbed areas.

Jurema preta was the only evergreen species studied. Although avidly browsed year-round by all types of livestock, the compound leaves are very small and frequently beyond reach of browsers. The dense wood is valuable for fenceposts, firewood, and charcoal.

Pau branco is used for construction, furniture, and fuelwood. The foliage is not normally browsed by sheep and goats, although cattle find it palatable (Braga 1960).

Treatments and Experimental Design

Cutting treatment consisted of traditional land clearing by commercial woodcutters using hand tools. The date of the seasonal treatments was determined by the rainfall pattern. Because trees are normally cut in the mid-dry season, this was considered a control treatment. The early dry-season plots were cut in July 1982, mid dry-season plots in November 1982, early rainy-season plots in late January 1983, and late wet-season plots in May 1983. All woody plants were cut, and the usable wood was removed. Plots were protected from grazing throughout the study.

A randomized block design with 3 replications was used at both sites. Each treatment was applied to 1 plot in each of the 3 blocks. Within the plots, a minimum of 6 healthy trees of each species studied were randomly selected from within the modal diameter class for the species in that stand. Stumps were cut at a standard 30 cm height and permanently marked with aluminum tags.

Double sampling (Cook and Stubbendieck 1986) was used to determine biomass production at the end of the first growing season after treatment (1983). Two coppicing stumps of each species from each plot were randomly selected for harvest. The height and diameter of the coppice clumps were measured, then all regrowth was cut from the stumps. The harvested material was separated into leaf and stem fractions, oven dried at 65° C for 48 hours and weighed. Regression equations were developed relating leaf and stem biomass production to height and diameter for each species and treatment. The height and diameters of the coppice clumps of all unharvested stumps were recorded and used as independent variables to predict biomass production. At the end of the 1984 growing season, coppice growth was cut from all previously unharvested stumps, separated, dried, and weighed.

Variables analyzed include stem, leaf, and total biomass and the ratio of leaf to stem biomass. Homoscedasticity was verified with Cochran's test (Guenther 1964). Analysis of variance was performed using the SAS statistical package (Statistical Analysis Systems 1986) and means were compared with Fisher's protected LSD test at $\alpha = .05$ (Steel and Torrie 1980).

Results and Discussion

1983 Biomass Production

With the exception of evergreen jurema preta, cutting late in the wet season does not allow enough time or suitable conditions for coppice growth. Responses to this treatment, therefore, are not readily apparent until rains begin the following growing season. For other treatments, however, some trends became apparent in the first year.

Based on comparisons of stem weight by the different species at the 2 sites, there are significant production differences among species in response to season of cut. Catingueira produced more stem biomass when cut at either time in the dry season, than if cut in the early wet season (Tables 1 and 2). The season of cutting had little effect on marmeliero production. The stem weight of pau

Table 1. Mean coppice production (g dry wt) of individual plants by season of cutting in Sobral, 1983.

	Sample size	Stem wt	Leaf wt	Total wt	Leaf/stem ratio
	n	$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$
Treatment/species			Catingueira		
early dry	12	312 a	286 a	597 ab	.89b
mid-dry	30	391 a	341 a	731 a	.91 b
early wet	17	139 c	271 a	410 b	1.88 a
			Marmeliero		
early dry	8	215 a	124 a	339 a	.52 a
mid-dry	11	166 a	138 a	304 a	.83 a
early wet	12	104 a	140 a	245 a	2.02 a
			Pau Branco		
early dry	20	569 b	321 b	890 b	.59 b
mid-dry	30	735 a	442 a	1176 a	.67 b
early wet	18	349 c	275 b	624c	.88 a
			Sabia		
early dry	19	399 a	241 a	639 a	.64 c
mid-dry	31	297 ab	212 a	508 a	.74 b
early wet	19	231 b	198 a	429 a	.89 a

For each species values within a column followed by the same letter are not significantly different ($P \leq .05$) by the LSD test (Steel and Torrie 1980).

Table 2. mean coppice production (g dry wt) of individual plants by season of cutting in Quixadá, 1983.

	Stem wt		Leaf wt		Total wt		Leaf/stem ratio	
	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$
Treatment/species		Catingueira						
early dry	18	249 a	—	—	—	—	—	—
mid-dry	28	204 a	—	—	—	—	—	—
early wet	18	41 b	—	—	—	—	—	—
		Jurema Preta						
early dry	17	3974 a	18	261 b	16	4012 a	15	.08 b
mid-dry	20	1837 b	20	392 ab	20	229 b	20	.22 b
early wet	22	1421 b	22	523 a	22	1944 b	20	.40 b
late wet	17	17 c	17	18 c	17	6 c	6	2.10 a
		Marmeliero						
early dry	19	137 a	—	—	—	—	—	—
mid-dry	23	184 a	—	—	—	—	—	—
early wet	19	214 a	—	—	—	—	—	—
		Sabia						
early dry	18	326 b	—	—	—	—	—	—
mid-dry	25	591 a	—	—	—	—	—	—
early wet	19	351 ab	—	—	—	—	—	—

For each species values within a column followed by the same letter are not significant different ($P<.05$) by the LSD test (Steel and Torrie 1980).

branco was significantly different for each season of cutting (Table 1). Unlike most species, it produced most when cut in the mid-dry season. There were differences in stem production by sabiá on the 2 sites (Tables 1 and 2). In Sobral, maximum stem production occurred after early dry-season cutting. Production following mid dry-season cutting was intermediate between production after early dry-season and early wet-season cutting. In Quixadá, mid dry-season cutting maximized sabia stem production. Jurema preta produced the most when cut in the early dry season (Table 2).

In 1983, leaf fall occurred simultaneously at both sites, precluding collection of leaf production data for most species in Quixadá. In Sobral, where leaf and stem data were available, the pattern of biomass production with season of cutting was similar for the stem and leaf fractions. Although leaves are the primary forage component, leaf material is more subject to loss or damage from storms or insects than stem material. Therefore, it should be noted that stem biomass was more readily measured and hence the most reliable variable examined.

In Sobral, the season of cutting did not affect leaf production of any species except pau branco. As with stem production, leaf production was maximized by mid dry-season cutting. Dry season leaf biomass of jurema is difficult to evaluate because the species is gradually exchanging leaves during this period. Leaf biomass from late wet-season treatments was lower from other treatments. For all species except marmeliero, the ratio of leaf biomass to stem biomass decreased with increasing time after treatment, supporting the observation that leaf production dominates the early phase of coppice growth.

1984 Biomass Production

Treatments were completed during the 1983 growing season, allowing all the remaining stumps an equal amount of growing time during 1984. Data were not available for the Sobral site in 1984, restricting further comparisons between the 2 sites.

No mortality occurred as a result of cutting, and results from 1984 were consistent with those from 1983. For all species except

Table 3. Mean coppice production (g dry wt) of individual plants by season of cutting in Quixadá, 1984.

	Stem wt		Leaf wt		Total wt		Leaf/stem ratio	
	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$
Treatment/species		Catingueira[1]						
early dry	12	1604	11	620	11	2250	11	.58
mid-dry	18	796	18	279	18	1075	18	.33
early wet	10	898	11	466	10	1390	10	.66
late wet	12	406	12	225	12	631	12	.66
		Jurema Preta						
early dry	12	5317 a	12	524 a	12	5841 a	12	.08 a
mid-dry	14	2082 b	14	191 a	14	2273 c	14	.10 a
early wet	12	3189 b	12	506 a	11	4004 b	11	.13 a
late wet	11	767 c	9	167 a	9	1061 c	9	.39 a
		Marmeliero						
early dry	12	438 a	12	181 bc	12	619 a	12	.58 a
mid-dry	16	613 a	16	289 a	16	902 a	16	.59 a
early wet	15	581 a	15	263 ab	15	844 a	15	.52 a
late wet	12	313 a	12	151 c	12	463 a	12	.93 a
		Sabia						
early dry	13	1186 a	13	591 a	13	1777 a	13	.52 a
mid-dry	19	1584 a	19	754 a	19	2338 a	19	.48 a
early wet	13	1330 a	13	540 a	13	1871 a	13	.41 a
late wet	13	457 b	13	225 a	13	681 b	13	.53 a

For each species values within a column followed by the same letter are not significantly different ($P<.05$) by the LSD test (Steel and Torrie 1980).
[1]This data not suitable for analysis of variance—see text.

marmeliero, stem biomass production by trees cut in the late wet-season continued to lag behind production by trees cut in any other season (Table 3). As in 1983, marmeliero stem production was not affected by the season of cutting. Jurema preta production was maximized by cutting early in the dry season. Only late wet-season cutting affected subsequent sabiá production. An analysis of variance was not done for catingueira because of large differences in the variance of the treatment groups. However, it appears that early dry-season cutting might maximize stem production.

None of the species' leaf biomass production was significantly affected by the season in which the tree was cut, nor was the leaf/stem biomass ratio significantly different between treatments for any species in 1984.

The season in which jurema preta, sabia, pau branco, and perhaps catingueira are cut influences the amount of stem tissue regrowing from remaining stumps. This response has important management implications. Desirable species that respond to season of cut should be cut during the dry season to maximize future production. Less desirable species should be cut late in the rainy season to minimize coppicing. This scheme favors production of desirable species, perhaps giving them a competitive advantage in the regenerating stand. When browse production is a goal, dry season cutting reduces the impact of treatment on forage production in the year of treatment because fallen leaves can be utilized before land clearing begins.

The lack of tree mortality suggests that seasonal cutting treatments alone are not sufficient to influence plant density. However, a reduced biomass response may indicate increased vulnerability to subsequent treatments such as browsing, burning, or slashing coppice growth (Hardesty and Box 1988).

The fact that leaf production in the second year was not affected by season of cut, and that the leaf/stem ratio tends to decline over time suggests that season of cutting cannot cause any long-term shift in leaf production relative to stem production. Observations of coppice growth in the third and subsequent years demonstrate that the leaf/stem ratio continues to decline for several years beyond the 2-year period reported here.

Browsing livestock consume large quantities of foliage and smaller amounts of shoot tips, branches, flowers, and fruit (Pfister and Malechek 1986). By the end of the second growing season, coppice growth had exceeded the reach of browsing animals, and most browse consisted of fallen leaves. This growth form constitutes a natural storage system for leaves which, once abcised, become an important forage source in the dry season. This study demonstrates that leaf production can only be increased by maximizing total growth, a large portion of which will be stem.

Our study was designed to determine if season of cutting, a factor known to affect coppicing of temperate trees, also affects coppicing in the caatinga. Although the study was not designed to test hypotheses regarding the mechanisms involved, some cautious speculation may be useful in interpreting our results.

Many temperate trees produce the greatest coppice growth when cut during the dormant season (Buell 1940, Blake 1972, DeBell and Alford 1972, Pringle et al. 1972, Steinbeck et al. 1972, Cremer 1973, Belanger 1979). In the semiarid tropics, this period corresponds to the dry season. In our study those species that were affected by season of cut produced the greatest coppice growth when cut at some point during the dry season. When a tree is leafless, it still has a continuing energy demand for respiration. This is true even if a major portion of its biomass is removed by cutting. Most nonstructural carbohydrates in trees are stored in the above-ground woody material (Kramer and Kozlowski 1960). When a tree is cut, the stump has only the reserves remaining in the stump and roots. How long the stump must depend on these limited resources before new leaves are produced becomes a critical factor in its survival.

In summary, cutting trees in the caatinga during the dry season allows time for the tree to coppice and the new shoots to produce and store carbohydrates before the next dry season. Cutting late in the rainy season does not allow the stump time to replenish lost carbohydrates, forcing it to survive the entire dry season on limited resources. As a consequence, minimal reserves are probably available for early rainy-season growth, and this may affect future production.

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