Response to cutting of *Larrea divaricata* Cav. and *L. cuneifolia* Cav. in the piedmont of Mendoza, Argentina

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Abstract

The cutting response of *Larrea divaricata* and *L. cuneifolia* was studied in the arid piedmont west of Mendoza, Argentina. Each species belongs to a vegetal community, *L. cuneifolia* is found in the lower level (until 1250 m) and *L. divaricata* in the upper one (between 1250- 2500 m). Four treatments with ten repetitions were analyzed in plants randomly chosen: T1: cut at ground level with a lopping shear, T2: cut at ground level with pick, T3: cut at 10 cm with the lopping shear and T4: cut at 20 cm with lopping shear. The initial and final height, volume and dry matter and the biggest and smallest diameter were obtained for each plant. The relation between volume and initial and final dry matter and height was analyzed through MANOVA factorial and compared with the Tuckey test ($p<0,05$). The functional relation between volume dry matter and height was estimated adjusting a regression model. In both species the best results were reached in treatments 3 and 4, height being a good indicator value for dry matter. The obtained turnovers were 18 and 17,7 years for T3 and T4 in *L. divaricata,* and 16,7 and 17,2 years for T3 and T4 in *L. cuneifolia,* respectively

Keywords

Andean, arid, shrubs, *Larrea,* sustainable, wood fuel

Introduction

The *Larrea* genus is presented as a case of non-continuous amphitropical distribution, spreading in the arid and semiarid regions of Argentina, Chile, Bolivia and Peru in South America, where it has four species (*L. divaricata* Cav. ssp. *divaricata, L. cuneifolia* Cav., *L. nitida* Cav. and *L. ameghinoi* Speg.). Through Mexico and SW of the US, in the Northern Hemisphere the genus is present with *L. divaricata* ssp. *tridentata* (DC.) Coville (Hunziker *et al.* 1977).

In Argentina *L. divaricata* ssp. *divaricata* has its domain at the Monte Phytogeographic province, reaching from the south of Jujuy at 29° SL until Chubut at 42-43°; *L. cuneifolia* also reaches the west of Argentina, mainly through the arid piedmont of the Precordillera.

In the Mendoza Precordillera *L. divaricata* ssp. occupies loose sandy soils, that are more capable of retaining moisture at depth (Méndez 1983). Similarly for the Northern Hemisphere, Hunt *et al.* (1973) indicated that *L. divaricata* ssp. *tridentata* showed a high requirement in the oxygen diffusion rate (ODR) for the radical growth. *L. cuneifolia* spreads through the lower piedmont ground, in deep, loamy-clay soils (Roig 1976, M. Carretero & Dalmasso 1992).

There exists abundant information on the *Larrea* genus (Johnston 1940; Morello 1958; Raven 1963; Barbour 1969; Hunziker 1971; Palacios *et al*, 1972; Palacios y Hunziker 1972; Yang 1967a, 1967b, 1968, 1970; Yang & Lowe 1968; Yang *et al.* 1976; Porter 1974; Simpson *et al.* 1977; Hunziker *et al.* 1977; Passera 1983; Cortez y Hunziker 1988; Martinez Carretero y Dalmasso 1992 among others). Nevertheless, there is no available information about the cutting response in spite of the fact that both species (*L. divaricata* and *L. cuneifolia*) are being cut at all times to be used as fuel, specially in the arid strip west of Argentina. There are places nearby the cities with marked desertification processes owed to this extracting activity. This is a common practice among the piedmont inhabitants of Mendoza. The traditional extracting method consists of uprooting of the plant with a pick so as to use the whole plant (root, crown and branches). This procedure causes an intense degradation of the community, resulting in a decrease of the vegetal cover, structure changes and intensification of the hydrical erosion processes (Pedrani et al. 1983). This study was carried out to evaluate the recovering capacity of both *Larrea* species after an initial cutting.

Larrea has no forage value and it is practically not eaten by the minor livestock . *Larrea* has a caloric power similar to *Prosopis flexuosa* (4,570 kcal/kg DM). Braun & Candia (1980) determined a caloric power of 4,631 kcal/kg DM for *L. divaricata* and of 4,618 kcal/kg DM for *L. cuneifolia*.

The world use of wood increases constantly, specially in the underdeveloped countries. Lusigi (1984) quotes an average use for food and construction of 0.785 DM /family/year and of 106 t DM/family/year for nomads in Kenia. FAO (1995) indicates a world use for 1990 of 1.4 billion tons of biomass (mainly as wood and carbon). For Argentina the scarce statistics indicate an annual use of 2.3×10^{6} t of wood, of which 80% corresponds to native woods, and it does not include the exploitation of the shrubby stratum. For the south of Mendoza, Candia *et al.* (1993) calculated a use of 5 t DM/family/shrub wood year for cooking and heating. Nevertheless there are still no statistics about wood extraction in the Andean piedmont.

On the other hand, field observations showed that plants consumed by small mammals (*Ctenomys* sp.) with cuts between 10-20 cm above the ground, mostly from *L. divaricata*, issue numerous sprouts. Similar observations were carried out by Valentine & Gerard (1968) in *L. divaricata* ssp. *tridentata* in New Mexico, were those plants cut between 10 and 45 cm height by small rodents and rabbits sprouted vigorously.

In the study area at 1,500 m *L. divaricata* ssp. *divaricata* reaches 162 cm mean height, while *L. cuneifolia*, at 1130 m , reaches 132 cm. For this last species Passera (1983) indicated a 120 cm height in the piedmont at 1050 m ., while Barbour & Diaz (1973) quoted 112 cm for *L. divaricata* ssp. *tridentata* at the Mohave desert and 86 cm at the Chihuahua one.

Methods

Study area

Both studied communities are located west of the Departamento de Luján, Mendoza, Argentina, at 33° 05´-69° 00´SL, one is found at the piedmont of Cerro Cacheuta, the other at the place named Pampa del Cebo. The *Larrea divaricata* ssp. *divaricata* corresponds to the upper vegetation belt with alluvial soils, and gravel in fine sandy matrix and a calcareous layer 40-50 cm deep. The general east downward slope is 7%. The *L. cuneifolia* community lies over the El Zampal Fm. (Polansky 1962) with deep soils, loamy-clay texture and 2-3% slope.

These areas were chosen because their communities are almost unaltered and in semi-confinement, and with no evidences of having been cut, otherwise the remaining piedmont suffers from different degrees of alteration owing to the anthropic action. On the other hand, both species are characterized by the homogeneous height and diameter, and by their distribution in the community. Moreover, the area is representative of zones with high agricultural potential.

The communities belong to the Monte phytogeographic province and they are each situated within the *Larrea* belt. The lower one belongs to *L. cuneifolia* between

750 – 1250 m, and the upper one to *L. divaricata* between 1250-2200 m , as described by Roig (1976). Rainfall records (1983-1988 period) were taken at the Estancia La Crucesita, located 5 km north of the study area (INCYTH unpublished data) (Table 1). The study was carried out during 5 years (1983 – 1988) and four cutting treatments were assessed: T1: cut at ground level with a lopping shear, T2: cut at ground level with pick, T3: cut at 10 cm with the lopping shear, and, T4 cut at 20 cm also with lopping shear. The normal treatment was not considered in the analysis because it means eradication of plants as well as structural and floristical changes. However,T2 treatment considers the use of a pick as an usual tool. Ten plants were chosen totally at random for the treatments at each vegetation belt. Plants were individualized with metal stakes. The cuts were done at the beginning of November 1983, before the summer precipitation. Each plant underwent the following measurements: height (taken between the highest branch top and the ground), largest diameter (between the extreme lateral branches), and perpendicularly the smallest diameter. Initial data were used as control in each treatment. In both species the data analysis were performed previously to correcting the final heights at ground level. After the observations the initial cut was done, the material so obtained was dried in a stove at 70° C until the constant weight was reached in order to get the initial dry matter. Measurements (height, largest and smallest diameters) were taken each three months during the first year, and each six months during the rest of the study. The final dry weight was determined when the study was over.

The starting and final volume of each plant was calculated at the time of the observations, assimilating the plants shape to an inverted cone of elliptical base, using the formula $V = DM/2 * dm/2 * \pi * h * 1/3$ (where *DM* and *dm* estimate the largest and smallest diameter respectively and *h* is the height). The values of volume and dry matter were transformed through the Log n function and adjusted at scale. The variance homogeneity was verified through the Hartley, Cochran and Bartlett test. Differences between treatments taking height, volume and initial and final dry matter into consideration were tested using MANOVA and compared with the Tuckey test ($p < 0.05$). The functional relation between volume, dry matter and height was estimated using a lineal regression model, and the correlation between them was also compared ($p < 0.05$) with the Pearson correlation coefficients.

The determination of the density of *Larrea* plants per hectare in each vegetation layer as well as the determination of the relations stump/aerial part and stem/leaf dry matter were done using 10 x 20 m plots, with 10 repetitions. The Point Quadrat method (Daget et Poissonet 1971) was used to determine the coverage of each species through 6 fixed transects of 30 m, with readings each 30 cm.

Results

Larrea divaricata

This species in general reacts favorably to the different cutting treatments, with low mortality percentages. The T1 and T2 treatments, both at ground level cut, presented 10% and 30% of plants death at the 11 and 18 months respectively, while during T3 and T4 all of the plants survived. Table 2 indicates the mean values and deviations for height, largest and smallest diameter and volume for each treatment, only for initial and final data.

Starting from MANOVA and considering the starting volume and initial dry matter, there are no significant differences ($p< 0.05$) between plants included in the study, evidencing the uniformity in regards to the shape and dry initial weight of the sampled plants. On the other hand, the analysis of the difference between initial and final dry matter did not result significant ($p < 0.05$) between the four treatments, which indicates a good response to the different types of cut.

The variance analysis considering the final volume ($p < 0.05$, $F (1, 38) = 2,76$) and the final dry matter ($p<0.05$, $F (1,34) = 0,31$) for the four treatments showed significant differences between T2 with respect to T1, T3 and T4. These three last ones do not differ among them. It is estimated that this difference is owed to the tool used in the plant that produces bigger injuries and damages the tissues.

The correlation analysis between the final dry matter and the final volume of the four treatments reached a significant r^2 of 0.77 ($p < 0.05$, $F (1, 34) = 117,3$). Taking into account the mortality percentages, and that T1,T3, and T4 treatments do not differ significantly in the final dry matter, the most adequate treatments are T3 and T4. T3 reaches a significant r^2 of 0.76 ($p < 0.05$, $F (1, 8) = 26,38$) between the final volume and the final dry matter, but there is no correlation between the final height and the final dry matter ($p < 0.05$). In T4 the correlation between final dry matter and final volume resulted with a significant r^2 coefficient of 0.93 ($p < 0.05$, $F (1, 8) = 109,20$) (linear regression equation: final dry matter Log = 11.77 + 1,0921* final vol. Log) . Considering the height of the plant at the end of the experience and the final dry matter, the significant r^2 is of 0.98 ($p < 0.05$) (regression equation of final dry matter Log = 0.018998 * final height), therefore height constitutes a good indicator value for the management rules of this species.

Fig. 1 shows the variation in the dry matter increases produced by each plant during the study in T4. In Fig. 2 the mean height growth can be observed in 10 repetitions for each observation in all treatments. Besides, from and important initial growth following a cut, a stabilization can also be observed in the growth of the sprouts length when the plants are reaching the height they had at the beginning of the experience. In this same figure, the observations have been put according to the summer or winter period. *L. divaricata* is a perennial with two growth periods, one spring-summer, the other autumm-winter, with two peaks one at the end of the summer (February) and the other in the winter (July).

This species only shows a significant correlation ($r2 = 0.44$, $p < 0.05$, $F (2, 77)= 30$) in T4 between the dry matter produced in each observation, the monthly mean precipitation accumulated during the two months before, and the mean temperature of the month when the observation was done. This was more noticeable at the summer peak of 1985 with an accumulated rainfall of 136 mm.

In *L. divaricata* 10 cm cuts, the stump is 39% of the dry matter and in the 20 cm cut it is 48%. The aerial dry matter in cuts of 20 cm shows a stem/leaf relation of 5:1 in weight. For the best treatments the initial dry matter was: T3: 2.0 ± 1.10 kg and T4: 3.0 ± 1.82 kg, and the final dry matter was: T3: 0.60 ± 0.41 and T4: 1.1 ± 0.87 kg.

Larrea cuneifolia

Starting from MANOVA and considering the starting volume and initial dry matter there are no significant differences between plants included in the study, evidencing the uniformity in regards to the shape and dry initial weight of the sampled plants.

This species showed to be very sensitive to cuts, resulting in high mortality percentages: T1: 70% from the 11^{th} month (40% at the 6^{th} month), T2: 90% from the 18^{th} month (30% at the 6^{th} month, 60% at the 11^{th} month), T3: 30% from the 27^{th} month, excepting in T4: 0%. Table 3 indicates the mean values and deviations for height, largest diameter, smallest diameter and volume for each treatment, only for initial and final data.

Considering only the most favorable treatments (T3 and T4), the variance analysis of the final dry matter ($p< 0.05$, $F (1, 13)= 0.13$) did not evidence significant differences between both, as well as for the difference between initial and final volume. On the contrary, there were differences between the final volume of T3 and T4, it being significantly higher ($p < 0.05$) in T4.

The particular analysis of each treatment showed for T3 a significant correlation of $r^2 = 0.93$ ($p < 0.05$, $F (1, 5)= 64.64$) between the final volume and the final dry matter. Besides, between the final dry matter and height a significant correlation of $r^2 = 0.68$ ($p < 0.05$, $F (1, 5)= 10.83$) was reached, resulting: Lg fdm = 60.6080 + 37.20656* height.

In the 20 cm cut, T4, the correlation between final dry matter and height is significant with $r^2 = 0.75$ ($p < 0.05$, $F (1, 6)=18,35$), resulting = Lg fdm = -2.939 + 0.04879* height. Fig. 3 shows the variation of the dry matter increases produced per plant in each observation for T4.

Just like *L. divaricata*, this species has two growth periods, one spring-summer and the other autumm-winter, with a peak at the end of the summer and a more uniform growth in the winter (Fig. 4). Even though here no correlation is achieved between precipitation, accumulated precipitation and mean temperature, and produced dry matter, the incidence of the higher precipitation between December and January 1984 is noticeable. In *L. cuneifolia* in the cut at 10 cm, the stump represents 23% of the dry matter and in the cut at 20 cm it represents 31 %, the relation stem/leaf in weight is of 7:1. For the most favorable treatments the initial dry matter was: T3 1.8± 1.38 kg, T4: 1.7 ± 0.67 kg, the final dry matter was T3: 0.35 ± 0.39 kg and T4: 0.51 ± 0.48.

Discussion

L. divaricata occupies the semi-arid upper belt of the piedmont with annual 250-280 mm precipitation, and *L.cuneifolia* the xeric lower belt with annual average 180 mm. In *L. divaricata* the higher humidity is evidenced by a moss stratum covering 28.64% of the soil, while in *L. cuneifolia* it only covers 8.9% (Martinez C. & Dalmasso 1992). This way the hydric deficit is lower in the upper belt, which would determine a lower mortality percentage of the plants after the treatment.

De Soyza et al. (1997) determined that the *L. divaricata* ssp. *tridentata* plants growing in environments with higher water limitation acquire the shape of an inverted cone with the upper branches inserted at 45° angles, while in those environments with no hydrical limitations their shape is rounded, with insertion angles smaller than 45°. In our case *L. divaricata* as well as *L. cuneifolia* present the shape of an inverted cone, even though *L. cuneifolia* is located at the lower piedmont level, indicated as arid by Minetti (1989).

In relation to the density of plants, cover and biomass, there appear differences between both species. *L. divaricata* reaches 405 plants/ha with an absolute cover of 17% and a dry aerial biomass of 964 g/plant and subterranean biomass (crown and roots until 30 cm length) of 623 g/plant. *L. cuneifolia* instead reaches 2100 plants/ha, an absolute cover of 15% and aerial and subterranean biomasses of 2310 and 696 g/plant respectively. Barbour & Diaz (1973) indicate 403 plants/ha of *L. divaricata* ssp-*tridentata* with an absolute cover of 7% for the desert of Sonora, and McLeary (1968) 667 plants/ha with an absolute *Larrea* cover of 6% for Oregon Pipe, in Sonora, with 205 mm rainfall per year. In sites at the Chihuahua desert the density increases, Burk & Dick-Peddie (1973) indicate 6420 plants/ha for Jornada with 12% absolute cover, and for Fillmore1 2824 plants/ha with 23% of absolute cover. On the other hand, Barbour *et al.* (1977) mention 300 g/plant for *L*. ssp. *tridentata* in Mohave and 700 g/plant at the Chihuahua desert, and, Burk & Dick-Peddie (1973) 1400 g/plant for Chihuahua.

In both *Larrea* species the new shoots come from adventitious buds, apparently neo-formed in the chlorenchyma of the stem. Morello (1955) graphics a chlorenchyma strip of approximately 100 µ for *L. divaricata* and *L. cuneifolia*, while Cannon (1908) indicates a 50 µ chlorenchyma in *L. divaricata* ssp. *tridentata* young stems. In the treatments with cuts at 10 and 20 cm there remain enough branches for the plant to recover, similar to that observed by Rachid (1947) in plants that have been repeatedly cut at the Cerrado (Brasil). Besides if the radical system remains untouched and the apical dominance is broken with the cut, the citocinines production would be high in respect to that needed to provide the rest of the biomass of the shoot, which would favor the differentiation of parenchyma cells to meristems of shoots bud. On the other hand the T4 shoots, at 20 cm height, showed a greater growth in both species, which would be associated to a greater availability of carbohydrates in the stem segment (Wenger 1953; Chang 1970) than in the cut at ground level treatments.

Even though the cuts when starting the test, were done at the beginning of November (beginning of summer) and before the summer precipitation when the plants were blooming, the influence of the phenologic state over the resprouting capacity should not be disregarded, as observed by James & Laude (1960) for *Adesnotoma fasciculatum* in the California desert. Stoeckler (1947) and Wenger (1953) associated the scarce new shoots in plants cut in the summer to the low reserve contents. In the case of *Larrea*, the cutting moment would not mean higher incidence because both species grow and have vegetative activity along the year. On the other hand Halls & Alcaniz (1965) indicate that in woody species of warm regions, the branches grow rapidly only during a brief time in the frost - free period. In the *Larreas* studied at the Andean piedmont this would not apply as they grow continuously. In our test the volume was recovered five years after only in treatments T3 and T4, in both species.

On the other hand, the recovery of the dry matter (final dry matter) considered by species and by treatment, in respect to the initial dry matter, represented: in *L.*

divaricata, in T3 = 27.7% and in T4 = 28.3% in five years. In *L. divaricata* the starting DM for T3 was of 2.16 k and of 3.56 for T4. The recovery reached 0.6 k Dm and 1.0 k DM respectively in five years, meaning 18 and 17.7 turnover years. In T1 in spite of the 32% recovery of the dry matter in the 5th year (15.6 turnover years), the cover and the volume per plant are significantly lower than in the starting values. T2 represents a very low recovery and a high plant mortality. In *L. cuneifolia* T3 recovered 30% of the biomass (initial DM: 1.97 kg and final DM: 0.5 kg, meaning 16.7 turnover years) and T4 recovered 29% (initial DM: 1.78 kg and final DM: 0.52 kg, meaning 17.2 turnover years).

In both species the use of the pick (T2) produces bigger injuries to the plant, damaging the tissues.

For the management of both species in the piedmont west of Argentina, T4 and T3 treatments are appropriate for *L. divaricata*, while T4 is good only for *L. cuneifolia*, in a way that does not endanger the plants survival and permits a good recovery of the plant cover (17 years mean turnover). Last but no least is to assess the answer of both species to successive cuts taking the turnover into account. On the other hand, considering that the general slope of the piedmont is 7-10% eastward and has intense superficial runnoff, the cuts must be done in 10 m stripes perpendicular to the slope.

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Figure 1. Variation in dry matter increasing (Lg DM) yielded for all plants in each observation, by T4, in *L. divaricata*.

Figure 2. Absolute mean growth in height for four treatments, in *L. divaricata* (Data stationally ordered).

Figure 3.. Variation in dry matter increasing (Lg DM) yielded for all plants in each observation, by T4, in *L. cuneifolia*.

Figure 4. Absolute mean growth in height for T3 and T4 in *L. cuneifolia* (data stationally ordered)

Table 1. Precipitation and temperature monthly records, 1983-88 period.

	J	F	M	A	M	J	J	A	S	O	N	D	∑ Annual
Ppmm													
1982	32	3	20	13	0	28	17	0	63	0	3	11	190
1983	39	12	4	0	12	21	8	59	28	31	23	31	244
1984	105	33	128	54	17	15	29	19	51	13	29	107	600
1985	91	27	16	8	16	16	25	8	42	15	50	64	308
1986	36	33	30	8	15	17	12	8	68	23	12	20	282
1987	18	58	51	12	1	15	48	28	6	28	64	69	398
1988	37	19	3	2	33	1	4	0	29	5	21	25	179
T°C													X Annual
1982	24	21.9	19.3	16.2	12.3	6	7.12	9.8	12.8	17.5	19.7	24.2	15.9
1983	23.4	22	19.7	15.2	9.8	4.5	5.1	8	11.2	18	21.8	24.6	15.2
1984	23.9	22.9	18.9	13.4	9.6	4.5	5.7	7.8	12.8	18	19.3	20.6	14.8
1985	22.4	21.9	20	14.4	11.6	8.16	6.26	9.4	13.2	17	21.8	23.7	15.8
1986	15.4	23	19.1	15.2	11.3	7.8	8.3	9.5	12.2	17.7	20.1	24.8	15.4
1987	25	23.8	19	15.2	7.8	7.6	8	8	12.2	17.9	21.2	22	15.6
1988	23.9	22.7	20	14.2	8.6	6	4.7	9.2	11.6	16.5	22.1	24.8	15.3

Table 2. Mean values and standard desviation of height, biggest and smallest diameter and volume for *L.divaricata*.

Date	Treatment	Height (cm)	Diam. biggest (cm)	Diam. smallest (cm)	Volume (cm^3)
Initial data	T1	155±31.71	228±71.18	205±58.30	2098506.9±1363839.2
	T2	157±27.40	244±37.44	205±53.17	2212170.7±1121847.2
	T3	175±31.71	261±52.32	225±36.05	2804938.2±1260942.0
	T4	149±23.86	228±51.97	182±45.53	1769690.7±854130.4
June/88 (final data)	T1	105±42.91	108±44.18	97±38.56	379890.6±223851.8
	T2	53±40.08	49±39.37	38±33.68	68100.4±99562.3
	T3	105±21.85	98±23.42	89±23.39	273140.5±186785.0
	T4	115±27.10	116±28.78	106±26.12	428053.7±341827.0

Table 3. Mean values and standard desviation of height, biggest and smallest diameter and volume for *L. cuneifolia*.

Date	Treatment	Height (cm)	Diam biggest (cm)	Diam. smallest (cm)	Volume (cm^3)
Initial data	T1	133±16.37	180±39.95	140±32.94	883830.1±312118.8
	T2	130±18.46	181±38.65	147±41.09	983007.6±556563.5
	T3	133±31.09	182±35.54	153±33.36	1039083.9±539863.2
	T4	131±11.32	178±47.15	140±34.31	906187.9±481551.9
June/88 (final data)	T1	18±29.90	20±33.04	17±28.84	18302.3±30524.6
	T2	Death			
	T3	55±40.71	62±52.07	52±44.18	120355.6±146845.2
	T4	92±19.22	89±31.58	77±29.92	205393.6±194478.2

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