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# Tree Productivity in the Semiarid Zone of Brazil

P.C.F. LIMA
*EMBRAPA-CPATSA, Cx.P. 23, 56.300, Petrolina, PE. (Brazil)*
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ABSTRACT

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The present study examined the wood and fodder productivity of *Leucaena leucocephala* (LAM) de Wit, *Prosopis juliflora* (SW) DC, *Eucalyptus camaldulensis* Dehnh, *Eucalyptus crebra* Muell., and *Anadenanthera macrocarpa* (Benth) Brenan, planted in Petrolina, Pernambuco State, as a semiarid zone in northeastern Brazil. The seedlings were planted in a plowed and harrowed field at a spacing of $3 \times 2$ m. Average height and survival rates were measured 1, 3, and 5 y after planting. A wood volume estimate was made 5 y after planting. The wood productivity of *Prosopis*, 15 $m^3$ $ha^{-1}$, was superior to *Leucaena* (11 $m^3$ $ha^{-1}$). Both species had lower productivity than *E. crebra* (24 $m^3$ $ha^{-1}$), but greater than *E. camaldulensis* (10 $m^3$ $ha^{-1}$) and *A. macrocarpa* (3 $m^3$ $ha^{-1}$). These productivity values are low compared to those of humid region species, but moderate for the semiarid zone, in relation to the wood productivity of 'caatinga' vegetation. The fodder productivity of *Leucaena* was 7.5 metric t of dry matter per ha per year. The pod productivity of *Prosopis* was estimated to be 6 t per ha per year.

## INTRODUCTION

The Brazilian semiarid zone covers approximately 1,160,000 $km^2$, which represents 75% of the northeastern region and 13% of the country. The natural vegetation is called 'caatinga', a deciduous woodland type that takes on a whitish-colored aspect during the dry season after the fall of the leaves. The trees are twisted and usually have thorns. The wood productivity is low and the exploitation is extensive and irrational. The wood is used commercially as an energy source in gypsum industries, cement factories, potteries and bakeries. On the farm the wood is used for small construction, fences and firewood.

Since the practice of afforestation (even with fodder species) is not common among the farmers, and the factories and industries that use charcoal as fuel do not have their own plantations, the Brazilian Government has initiated reforestation programs for northeastern Brazil. Consequently, several forestry companies are searching for information about the establishment, management and productivity of appropriate trees for the Brazilian semiarid zone.

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The number of species available for economical exploration in this zone is very limited. Only *Prosopis juliflora* (SW) DC is used in Government programs for reforestation in the semiarid zone, but studies by the Agricultural Research Center for the SemiArid Tropics (CPATSA) have demonstrated the ability of *Eucalyptus crebra* Muell., *Eucalyptus camaldulensis* Dehnh and *Leucaena leucocephala* (LAM) de Wit to grow fast, with a good survival percentage. These studies also showed that *Anadenanthera macrocarpa* (Benth) Brenan ('angico') grew more than any of the other native species (Silva et al., 1980; Pires and Ferreira, 1982; Lima et al., 1982b).

This paper reports on the wood and fodder productivity of all these species in the semiarid region of Petrolina, Brazil.

## CHARACTERISTICS OF THE REGION

Petrolina is situated at 09°09′ latitude south and 40°27′ longitude west, at an altitude of 365 m. The landscape is a gently undulating one, broken by a few rocky hills. In general the soils are shallow Latosols with a low water -holding capacity and low organic matter content.

According to the Köppen climatic classification, the climate of the region is of the BSh type with irregular rainfall, concentrated in 2–4 months of the year. Normally, the annual dry season begins in May and extends through December. In Petrolina the average rainfall measured over 22 years is 578.1 mm, and the average temperature is 27°C. The annual rainfall was 510 mm in 1979; 536 mm in 1980; 500 mm in 1981; 342 mm in 1982; 540 mm in 1983 and 654 mm in 1984.

Forest inventories carried out by Tavares et al. (1970) and Lima et al. (1979) estimated the wood volume, with a diameter at breast height (DBH) greater than 5 cm, to be 7 and 12 $m^3$ $ha^{-1}$, respectively.

Cattle, sheep and goats are the main livestock in the region. The limiting factor for livestock production is the low quantity and quality of dry season forage. Fifteen to twenty ha of 'caatinga' vegetation are required to feed one head of cattle in this region (Salviano et al., 1982).

## ESTABLISHMENT OF SPECIES

Introduction trials of *Eucalyptus* in the semiarid zone of northeastern Brazil have been conducted by EMBRAPA (Brazilian Agricultural Research Corporation) to define the best species and provenance. In Petrolina, 13 species and 90 provenances of *Eucalyptus* were introduced prior to 1984.

The first experiments were set up in 1979 in a randomized complete block design with the same number of replicates for all the treatments. Ten species of *Eucalyptus* were introduced from different provenances including: *E. camaldulensis,* 10 provenances; *E. alba,* 7 provenances; *E. exserta,* 4 provenances; *E.*

TABLE 1

Mean survival rates of *Eucalyptus, Leucaena, Prosopis* and *A. macrocarpa* in Petrolina

| Species | Provenances | Survival (%) | | |
|---|---|---|---|---|
| | | 1 year | 3 years | 5 years |
| *E. camaldulensis* | Australia (10923)[a] | 100 | 100 | 86 |
| *E. crebra* | Australia (6946)[a] | 98 | 96 | 94 |
| *L. leucocephala* | Local | 100 | 100 | 90 |
| *P. juliflora* | Local | 100 | 100 | 98 |
| *A. macrocarpa* | Local | 93 | 93 | 93 |

[a] Australian code.

*crebra,* 2 provenances; *E. nesophylla,* 4 provenances; *E. polycarpa,* 3 provenances; *E. tesselaris,* 2 provenances; *E. urophylla,* 1 provenance; *E. grandis,* 1 provenance; and *E. citriodora,* 1 provenance. The results, five years after planting, showed that *E. crebra* and *E. camaldulensis* were the best. The provenances 10533, 10510 and 10923 of *E. camaldulensis* were the best among the 10 tested provenances, with a survival rate higher than 85%. For *E. crebra* both provenances tested (11958 and 6946) had good growth with a survival rate higher than 92%.

Meanwhile, CPATSA is measuring the productivity of 12 native species in Petrolina. The first results three years after planting, show that *Anadenanthera macrocarpa, Tabebuia impetiginosa* and *Caesalpinia ferrea* have the greatest growth. This study uses a randomized complete block design with 3 replicates with 16 plants per plot, spaced $3 \times 2$ m. Characteristics of soil, site, seed origin, seedling production and methods of planting for all 12 species are described by Lima et al. (1982b).

A study of *Leucaena leucocephala* and *Prosopis juliflora* to examine survival, wood and fodder production in Petrolina was initiated in 1979. The experimental design was a randomized complete block with 5 replicates with 25 plants per plot, spaced $3 \times 2$ m. The first results showed these species to be suitable for the semiarid region (Lima, 1982). In northeastern Brazil, plantations of *Leucaena* are rarely used for firewood, but people use it for cattle feed.

The survival percentages for the best species (*E. camaldulensis, E. crebra, L. leucocephala* and *P. juliflora*) from the results obtained in the different experiments established in Petrolina, five years after planting, are given in Table 1. The data clearly show a good adaptation of the exotic species compared to *A. macrocarpa,* a native species of caatinga.

A locust (*Stiphra robusta* Mello-Leitão) was observed attacking the trees in the summer. The fodder species, especially *Leucaena* (Moraes et al., 1980), were attacked by this locust, reducing the fodder available to cattle. *A. macrocarpa* and *P. juliflora* were less susceptible to the locust than *Leucaena.*

TABLE 2

Mean growth and DBH of *Eucalyptus, Leucaena, Prosopis* and *A. macrocarpa* in Petrolina

| Species | Height (m) | | | DBH (cm) 5 years |
|---|---|---|---|---|
| | 1 year | 3 years | 5 years | |
| *E. camaldulensis* | 2.8 | 4.5 | 5.4 | 4.5 |
| *E. crebra* | 2.2 | 5.1 | 6.1 | 6.5 |
| *L. leucocephala* | 3.3 | 4.1 | 4.2 | 3.4 |
| *P. juliflora* | 2.2 | 3.2 | 3.2 | 2.6 |
| *A. macrocarpa* | 2.3 | 2.5 | 2.6 | 3.2 |

Twig girdling insects (*Oncideres* sp.) were observed on branches of *Leucaena* and *Prosopis*. The attack was more intensive on *Prosopis* than *Leucaena*. Termites were observed in the stems of *A. macrocarpa* but they caused no apparent damage to the plants.

Table 2 shows the growth of different species 1, 3 and 5 y after planting. In the first year *L. leucocephala* had the greatest height but its growth slowed from the third year. The same was true for *Prosopis*. This was probably due to the competition among the trees for water and nutrients because of the spacing used (3×2 m).

Considering the irregular rainfall in Petrolina during the period of study, the growth in height of *E. crebra* and *E. camaldulensis* was very good. Goor and Barney (1976) estimated the height growth of *Eucalyptus* at 1 m or more per year, for areas with less than 500 mm of rainfall. In Açu-Rio Grande do Norte a region with similar rainfall conditions, Pires and Ferreira (1982) found that *E. camaldulensis* has reached a height of 8.4 m with a 48% survival rate, five years after planting.

Souza and Carvalho (1984) examined the performance of eight provenances of *E. camaldulensis*, three years after planting in Teresina-Piauí, a region with 900 mm of rainfall per year on average. The most productive provenances, 11420, 10920 and 12139, reached 11.9 m, 11.7 m and 10.8 m in height, respectively, with a 100% survival rate. Results obtained by CPATSA during a similar trial of *E. camaldulensis* established at the same time in São Gonçalo-Paraíba, a region similar to Teresina, showed heights of 11.2 m, 10.9 m and 10.1 m after three years of growth for the provenances 12139, 11420 and 10920, respectively. The best survival rate (97%) was observed for the provenance 12139 (87% for the other two). In Petrolina, provenance 12139 grew to 4.2 m, with 31% survival, three years after planting. The provenances 10920 and 11420 grew to 4.0 m and 4.3 m and had a survival rate of 85 and 75%, respectively (Lima and Pires, 1985).

TABLE 3

Total wood and volume increment of the most promising species for Petrolina region

| Species | Wood volume ($m^3\ ha^{-1}$) | | Volume increment ($m^3\ ha^{-1}\ y^{-1}$) |
|---|---|---|---|
| | 3rd year | 5th year | |
| *E. camaldulensis* | 7 | 10 | 2.0 |
| *E. crebra* | 15 | 24 | 5.0 |
| *L. leucocephala* | 7 | 11 | 2.2 |
| *P. juliflora* | 8 | 15 | 3.0 |
| *A. macrocarpa* | — | 3 | 0.6 |

WOOD PRODUCTION

Both the tortuosity and bifurcation of the stems were taken into account when estimating the wood volume for the species. *Leucaena* and *Prosopis* had an average of two and six stems per plant, respectively. In this study all large shoots beginning below breast height were considered to be stems. The *Eucalyptus* had only one stem without tortuosity while *A. macrocarpa* had some bifurcations which were not considered because the branches were too short and thin.

Table 3 shows that the volume of *Prosopis, Leucaena* and *E. camaldulensis* was practically the same in the third year, and half that of *E. crebra.* In the fifth year the wood production of *Prosopis* (15 $m^3\ ha^{-1}$) was greater than *Leucaena* (11 $m^3\ ha^{-1}$). Both these species had lower production than *E. crebra* (24 $m^3\ ha^{-1}$), but greater than *E. camaldulensis* (10 $m^3\ ha^{-1}$) and *A. macrocarpa* (3 $m^3\ ha^{-1}$).

For *Prosopis,* the volume production in Petrolina (3 $m^3\ ha^{-1}\ y^{-1}$) was compatible with Webb's estimates (1980) of 3 to 5 $m^3\ ha^{-1}\ y^{-1}$ in a region with an annual rainfall of 400–500 mm. For *E. crebra,* the volume production was below the estimates of 10 $m^3\ ha^{-1}\ y^{-1}$ made by Goor and Barney (1976).

The wood productivity in Petrolina for *Eucalyptus, Prosopis* and *Leucaena* could be further increased through studies on plant spacing, fertilization, soil management and the use of water catchment basins.

The average wood volume increment for *Leucaena* was 2.2 $m^3\ ha^{-1}\ y^{-1}$, with a $3 \times 2$ m spacing. More recent research done by CPATSA has demonstrated that a $1.5 \times 1.0$ m spacing gives nearly twice the volume production of the $3 \times 2$ m spacing (Table 4). There was a statistical difference in diameter for the treatments tested, but not in plant height. In the closer spacings the stems were very thin, without branching.

TABLE 4

Mean survival, height, DBH and volume for different spacings of *Leucaena* in Petrolina

| Spacing (m×m) | Survival (%) | Height (m) | DBH (cm) | Volume $m^3\ ha^{-1}$ |
|---|---|---|---|---|
| 1.0×1.0 | 66 | 4.0 | 2.6 | 11.4 |
| 1.5×1.0 | 84 | 4.3 | 3.0 | 13.6 |
| 2.0×1.5 | 91 | 4.5 | 3.4 | 11.2 |
| 3.0×1.5 | 95 | 4.3 | 3.2 | 6.8 |
| 3.0×2.0 | 86 | 4.6 | 3.6 | 6.2 |
| 3.0×2.5 | 96 | 4.2 | 3.6 | 5.2 |

## FODDER PRODUCTION

Economically significant pod production of *P. juliflora* in northeastern Brazil begins in the fifth year after planting. After the 20th year the pod production begins to decrease, so the trees should be harvested for furniture and flooring (Nobre, 1982).

The pod production in Petrolina, according to experimental results from 10 plants randomly sampled from a population of 35 trees, spaced approximately 15×15 m and with 100 $m^2$ of canopy area per tree, is estimated to be 6 t $ha^{-1}$ $y^{-1}$. The experimental site was in an experimental irrigation station that probably had a high water table. The total pod number of *P. juliflora,* was estimated on the basis of the average monthly pod production of trees of the same age from May 1983 to March 1985 (Table 5). In the first year of observation the major flowering period began in May and in the second year in June. The greatest flowering occurred in months that had no rainfall.

Even though this plantation was 15 years old there was great variation in pod production, which ranged from 5 to 117 kg per plant. This variation could well be due to genetic or physiological disturbances; a similar variation occurred in the second year of measurements.

CPATSA is currently selecting trees of *P. juliflora* with superior pod production that will be vegetatively propagated by rooted cuttings. With this selection

TABLE 5

Average pod production from 10 trees of *P. juliflora* in Petrolina

| Year | Production (kg) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1983 | - | - | - | - | - | 4.8 | 23.2 | 9.8 | 4.8 | 3.7 | 4.3 | 0.9 |
| 1984 | 0.3 | 1.3 | 1.5 | 2.5 | 1.6 | 0.6 | 0 | 2.4 | 42.3 | 15.4 | 19.9 | 23.2 |
| 1985 | 12.9 | 0 | 0 | - | - | - | - | - | - | - | - | - |

and planting method it is hoped to increase pod production in the region by more than 80%.

There is no information on wood and pod production for *P. juliflora* in association with buffel grass (*Cenchrus ciliaris*) in the semiarid northeast of Brazil. However, research done by Ribaski (1983) in CPATSA, showed that it is necessary to eliminate the grass within a 1 m radius of the trunk of the trees in the establishment phase of this association. The *P. juliflora* survival rate in this trial at nine months was 10% without weeding, 90% with a 2 m diameter weeding and 100% when there was no association with buffel grass.

*P. juliflora* is also planted with *Opuntia* in this region. The current results from experiments at the CPATSA experimental station show that the growth of the trees is not affected, but the pod production is delayed. Although there was a 15% increase in the fresh weight of the *Opuntia,* this is not statistically significant. The *Prosopis* was planted with a spacing of $10 \times 10$ m and *Opuntia* in two double rows, spaced at $3.0 \times 0.5$ m. The spacing between the double rows of *Opuntia* is 1.5 m. In isolated plantings, spaced at $10 \times 10$ m, *P. juliflora* pod production began the second year after planting.

The fodder productivity of *Leucaena* in Petrolina was previously estimated to be 7.5 t $ha^{-1}$ $y^{-1}$ of dry matter, with three cuttings a year (Lima et al., 1982a). The plant spacing was $0.5 \times 1.0$ m. The dry matter production of *Leucaena* in the Brazilian savana (1000 mm rainfall) is 13 t $ha^{-1}$ $y^{-1}$ for closer spacings (1 to 2 m between rows), and 5.5 t $ha^{-1}$ $y^{-1}$ for spacing (5 m between rows) that permits interplanting with other crops (Kluthcouski, 1980). The results of more recent studies by CPATSA, in Petrolina, with a spacing of $3 \times 2$ m, and different cultivars of *Leucaena* are shown in Table 6. The greatest production of dry matter is observed for K62, K8, K28 and K72. There are differences among provenances of the same cultivar, probably due to drought tolerance in Petrolina conditions.

## CONCLUSIONS

The results of research with *Prosopis, Leucaena, Eucalyptus crebra* and *E. camaldulensis* show the viability of these species for afforestation programs in the semiarid zone of Brazil. The problems created by insects such as *Oncideres* and termites are minor compared to the problems of establishing the trees on various soil types with irregular rainfall.

Good soil management, fertilization, and plant selection are probably the key practices which could increase production and survival rates, and help alleviate the firewood shortage in this region. For example, it is estimated that the average consumption of firewood by a family of 5 in this region is approximately 6.7 $m^3$ $y^{-1}$. In this case it would be necessary for each family to afforest 4–5 ha, so that 1 ha could be cut every year, beginning in the third year, to meet their needs for firewood for cooking. Indeed, an equal area of 'caatinga' vege-

TABLE 6

Total edible dry matter and total woody material of different varieties of *Leucaena* in Petrolina

| Cultivar | Provenances[a] | Uniformity cut (1 year after planting) | | 4 and 8 months after uniformity cut | | |
|---|---|---|---|---|---|---|
| | | Edible dry matter (kg $ha^{-1}$) | Woody material (kg $ha^{-1}$) | Edible dry matter (kg $ha^{-1}$) | Woody material (kg $ha^{-1}$) | Total (kg $ha^{-1}$) |
| Unknown | Petrolina-PE | 2.3 | 1.2 | 2.1 | 1.2 | 3.3 |
| K 4 | Sete Lagoas-MG | 3.3 | 1.4 | 4.5 | 2.3 | 6.8 |
| K 6 | Linhares-ES | 3.0 | 1.6 | 3.3 | 2.1 | 5.4 |
| K 8 | Linhares-ES | 3.5 | 2.1 | 5.5 | 4.0 | 9.5 |
| K 8 | Sete Lagoas-MG | 3.1 | 2.1 | 3.8 | 2.1 | 5.9 |
| K 28 | Sete Lagoas-MG | 3.6 | 2.4 | 5.0 | 2.9 | 7.9 |
| K 29 | Sete Lagoas-MG | 2.7 | 2.0 | 2.6 | 1.9 | 4.5 |
| K 58 | Sete Lagoas-MG | 2.7 | 2.2 | 2.5 | 1.6 | 4.1 |
| K 62 | Linhares-ES | 4.4 | 2.4 | 5.0 | 2.8 | 7.8 |
| K 67 | Linhares-ES | 2.0 | 1.3 | 2.7 | 1.8 | 4.5 |
| K 67 | Sete Lagoas-MG | 3.0 | 1.8 | 4.4 | 2.3 | 6.7 |
| K 72 | Linhares-ES | 2.2 | 1.3 | 2.9 | 1.9 | 4.8 |
| K 72 | T. Freitas-BA | 2.2 | 1.6 | 3.2 | 2.0 | 5.2 |
| K 72 | Sete Lagoas-MG | 4.1 | 2.9 | 4.4 | 2.7 | 7.1 |
| K132 | Sete Lagoas-MG | 2.3 | 1.2 | 3.2 | 1.7 | 4.9 |
| Unknown | Sobral-CE | 2.8 | 1.6 | 4.3 | 2.2 | 6.5 |

[a] The Brazilian states are abbreviated as follows:PE = Pernambuco, ES = Espirito Santo, MG = Minas Gerais, BA = Bahia, CE = Ceara.

tation would not produce the same wood volume by natural regeneration. Reforestation with *A. macrocarpa,* a native species, would require eight, five and four times the area of *E. crebra, P. juliflora* and *L. leucocephala,* respectively, to satisfy the same wood demand.

The principal use for *Leucaena* in the semiarid zone of Brazil is forage production. A screening trial for forage production identified K62, K8, K28 and K72 as promising varieties.

The most promising way to increase *P. juliflora* pod production is through the use of cuttings from superior trees.

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