Establishment of *Leucaena leucocephala* with high sowing density under coconut (*Cocus nucifera*) tree

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A study was conducted on a soil with loamy-sandy texture to assess the agronomic, physiological and productive performance of *Leucaena leucocephala* in high sowing density under coconut tree. A random block design was used with factorial fit. The factors analyzed were: sowing density, with three levels of 40, 60 and 80 thousand plants of leucaena/ha, and tree age, at 5, 40, 55, 70, 85 and 100 d, with three replicates. The sowing was conducted on February 2009, at depth from 2 to 3 cm. The seeds were scarified and inoculated with rhizobium and mycorrhizae. After 20 d the tree emerged, the treatments were fertilized with the formula 00-20-10-20, provided by diatom land in dosages of 700 kg/ha. The manual control of weeds in the area was conducted. In all the variables studied there was interaction effect ($P < 0.001$). The best values found at 100 d of age were for the treatment with 80 thousand plants of leucaena/ha in stem diameter (1.27 cm), dry weight of leaves (49.54 g), dry weight of plant (72.61 g), biomass production (6159 kg/ha), productive rate (61.59 kg DM/d/ha) and water use efficiency (6.84 kg DM/m^3). These numbers were statistically similar to those obtained with 60 thousand plants of leucaena/ha, for plant height (133.67 and 138.28 cm) and number of leaves (23.94 and 24.72). The sowing of 80 thousand plants of leucaena/ha associated with coconut tree, as high density system, could be proposed as alternative for intensifying the agrosilvopastoral systems in the tropical area.

Key words: *leucaena, multiestratum, intensification, biomasa, grazing.*

The production of coconut trees in Colima state, Mexico, is one of the fruit activities of great importance as there are at about 13.000 thousand ha, most of them located in the coastal area. Due to the ups and downs of the fruit prices, producers develop different combinations, originating multiplicity of agrosilvopastoral systems. Combinations with fruit trees such as mango, lemon, banana; with cereals such as maize and sorghum (Ordaz and Pérez-Zamora 1998) and with native and improved pastures such as Guinea grass (*Panicum maximum*), signal grass (*Brachiaria brizantha*), star grass (*Cynodon plectostachyus*) (Palma 2006) and CT-115 (*Pennisetum purpureum*) (Rodríguez 2008), among others, are conducted for cattle rearing, although with low productive results (Palma 2006, Montiel *et al*. 2006 and Mazorra 2007).

In cattle rearing, the use of protein forages like *Leucanea leucocephala* (García *et al*. 2008 and Ruiz *et al*. 2008), is one of the alternatives that could increase the productive indicators, although Reynolds (1995) studied the combination of coconut tree with *Leucanea leucocephala* and recommended low plantation density. It is necessary to study options to intensify the agrosilvopastoral systems, either for the increase in the sowing density (Palma 1997 and Murgueitio 2009) or for the optimization of the space arrangements and strata used (Nahed 2008 and Bautista *et al*. 2011). Options like these allow the development of strategies to increase the system productivity.

The objective of this research was the establishment of waxe (*Leucaena leucocephala*), with sowing densities of 40, 60, and 80 thousand plants/ha under coconut (*Cocus nucifera*) tree and assessments at 40, 55, 70, 85 and 100 d of age.

Materials and Methods

The experiment was conducted in the Bovine Production Unit of dual purpose cattle in the Agricultural and Forestal Education Center (CECAF), located in Caleras, Tecomán municipality, at 47 km of the Colima-Manzanillo highway. It is geografically located at 18° 57´ 43´´ North latitude and 103° 52’ 47’’ West longitude, with 59 m a.s.l. these data were obtained from a portable geopositioner (GPS), Garmin e-trex mark, venture model.

The weather conditions of the cattle unit are typical of a AW0 climate, defined as dry tropic. The dry season predominates, in a period from seven to eight months, and the rainy season lasts from four to five months. The annual mean rainfall is of 600 mm the and average temperature of 70 % (CNA 2004).

The type of soil is of recent alluvial formation, with loamy-sandy texture (sand 56.24 %, loam 21.08 %, clay 22.68 %). Its pH is of 7.5; 2.42 % organic matter, 2.05 Mmhos/cm of electric conductivity and 21.78 Meq/100g of soil of cationic interchange capacity (Laboratory of Soils Analysis from the National Institute of Agricultural and Cattle Forestal Researches, Experimental Field Tecomán).

The age of the coconut plantation is of 45 years. It is at about 25 m height, and a plantation frame of 8 x 8 m. The sowing of leucaena took place on February 2009. The certified seed of leucanea was used, with minimum germination of 80 %. The seeds were scarified by hydrothermy and were inoculated with mixture of rhizobium and mycorrhizae (Rey *et al*. 2005). A plantation system with one row was conducted, with 1.6 m, 2.40 m and

3.20 m between furrows (for the densities of 80, 60 and 40 thousand plants/ha, respectively). Drill sowing was used for the required population. The sowing depth was of 2-3 cm. All treatments, at 20 d of tree emergence, were applied natural mineral fertilizer, in doses of 700 kg/ha, with diatom land base.

In order to evaluate the leucaena establishment, six samplings were conducted per useful plot, of one linear meter each. Three plants were measured in each sampling. The agronomic variables were: height, plants per meter, number of leaves, stem diameter (Medina *et al*. 2007), biomass production (dry weight of leaves, dry weight of stem, dry weight of the whole plant, dry matter yield). The physiological variables growth rate, productive rate and leaf/stem ratio were calculated. An air forced oven was used at 65°C for 48 h to determine the DM. Five periods of study were performed biweekly since 40 d of age of the tree.

The treatments were distributed according to random block design with factorial fit (3 x 5). One of the factors was the tree sowing density with three levels (40, 60 and 80 thousand plants/ha) and the other, the plant age, with five ages (40, 55, 70, 85 and 100 d). Three replicates were conducted per treatment. The experimental plot surface was of 880 m^2 (11 x 80 m). The useful plot was of 648 m^2. The analysis of variance was applied for the variables under study and Tukey test, to determine the multiple differences of the means ($P < 0.05$) (Montgomery 2004). The data were processed with Statistix (1998).

Results and Discussion

The best results, in terms of height and number of leaves, were obtaiend with 60 and 80 thousand trees/ha at 100 d of age (table 1). The variable plants per linear meter showed the best value for the treatment with 40 thousand trees/ha, at 40 d of age. There was a tendency to decrease in this treatment as the tree age increased. It was stable in the rest. This is due to the competence among the waxe plants when the plant height was of about 30 cm, limiting its growth. Likewise, the variable stem diameter showed the highest value in the treatment with 80 thousand trees/ha, at the age of 100 d. There was a linear performance as the tree age increased.

The highest DM contents of the plant were obtained at 40 and 55 d of age (table 2) in respect to the beginning of the establishment, at 40 and 55 d of age. The dry weight of leaves and plant and the DM yield had similar performance. The best value was achieved with 80 thousand plants/ha at 100 d of age. This treatment was three and two times higher compared with the treatments with 40 and 60 thousand plants, respectively, and at the same age.

The highest sowing density (80 thousand plants/ha) had the maximum DM value with 6.0 t/ha at 100 d of age. This production surpasses the data of González *et al*. (2003). These authors indicated values of 1.79 t DM/ha/cut in a study with sowing densities of 40.000 plants/ha, supported with sprinkling every 28 d, different cut frequencies and harvest at seven months of establishment. This difference could be attributed to the sowing density and the water availability in this study. If these data are compared with the initial results, corresponding to the establishment at 100 d of age, a potential of biomass production hardly explored would be denoted.

The variables of biomass production showed

Table 1. Agronomical characteristics of *Leucaena leucocephala* with different growth age and sowing density

Age (days)	Density (trees/ha) (thousands)	Height (cm)	Plants/m	Leaves	Stem diameter (cm)
100	80	138.28^{a}	13.55^{de}	24.72^{a}	1.27^{a}
100	60	133.67^{a}	15.11^{b}	23.94^{a}	1.04^{b}
100	40	112.83^{b}	14.50^{bcd}	18.16^{b}	0.88^{bc}
85	60	111.11^{b}	15.16^{b}	16.44^{b}	0.75^{cd}
85	40	100.78^{b}	14.38^{bcde}	15.38^{b}	0.66^{d}
85	80	98.56^{b}	13.22^{e}	16.27^{b}	0.78^{cd}
70	60	76.06^{c}	14.94^{bc}	10.22^{c}	0.36^{ef}
70	40	63.89^{c}	14.38^{bcde}	9.33^{cd}	0.42^{e}
70	80	63.39^{c}	13.77^{cde}	8.8^{3cd}	0.33^{efg}
55	60	29.61^{d}	15.11b	6.72^{cde}	0.22^{fgh}
55	80	29.17^{d}	14.27^{bcde}	6.38^{cde}	0.30^{efg}
55	40	28.72^{d}	14.66^{bcd}	5.72^{de}	0.19^{gh}
40	40	12.56^{e}	17.11^{a}	4.39^{e}	0.11^{h}
40	80	12.47^{e}	13.77^{cde}	5.94^{de}	0.13^{h}
40	60	12.33^{e}	15.16^{b}	4.77^{e}	0.11^{h}
ME		4.25	0.34	1.08	0.04
P		***	***	***	***

^{abc}Values with different letters in the same column differ significantly at P < 0.001***

Table 2. Characteristics of *Leucaena leucocephala* biomass production at different age and sowing density

Age (days)	Density (trees/ha) (thousands)	Height (cm)	Plants/m	Leaves	Stem diameter (cm)
100	80	51.11^{a}	49.54^{a}	72.61^{a}	6159.0^{a}
100	60	51.27^{a}	29.70^{b}	41.27^{b}	2545.0^{b}
100	40	49.27^{ab}	25.51^{bc}	36.50^{bc}	1643.0^{bcde}
85	60	47.94b	24.29^{bc}	29.77^{bcd}	1853.0^{bcd}
85	40	49.27^{ab}	21.49^{bcde}	26.33^{cde}	1177.0^{cdef}
85	80	49.72^{ab}	23.60^{bcd}	30.38^{bcd}	2489.0^{b}
70	60	50.33^{ab}	14.43^{efgh}	17.55^{defg}	1076.0^{cdef}
70	40	49.33^{ab}	15.82^{defg}	19.11^{defg}	854.0^{def}
70	80	49.77^{ab}	18.68^{cdef}	23.94^{cdef}	2043.^{0bc}
55	60	42.00^{c}	10.59^{fghi}	13.55^{efg}	839.0^{def}
55	80	43.72^{c}	11.09^{fghi}	14.16^{efg}	1252.0^{cdef}
55	40	38.50^{d}	10.31^{ghi}	12.72^{fg}	577.0^{f}
40	40	35.16^{e}	5.69^{i}	6.94^{g}	367.0^{f}
40	80	36.77^{de}	6.59^{hi}	8.05^{g}	690.0^{ef}
40	60	37.00^{de}	7.56^{hi}	9.22^{g}	575.0^{f}
ME		0.73	2.35	3.75	302 .0
P		***	***	***	***

^{abc}Values with different letters in the same column differ significantly at P < 0.001***

values with linear tendency to increase as the tree age increased (table 2). This phenomenon was previously studied and described by Palma (1997) for Gliricidia in establishing high sowing density. This performance could indicate the possibility of keeping this type of grassland for a longer productive time in a silvopastoral system, because the high density would help surpassing the limitations of tropical cattle rearing (Palma *et al.* 2000).

The sowing densities in the experiment were superior and with better results in their components, compared with those studies conducted in Asia with leucaena, in shade conditions under coconut tree. They also differ from those reported by Nitis *et al.* (1991), who stated that the sowing densities may not exceed 1.500 plants of leucaena/ha. Besides, they are different from that referred by Reynolds (1995), who indicated densities of 5000 trees/ha of leucaena. Both studies were conducted in shade conditions, under coconut tree. Although recently densities from 7 to 20 thousand plants/ha are proposed in multi-strata systems to intensify the silvopastoral systems (Ibrahim *et al.* 2007), the densities in this experiment exceed that in the literature. This implies a new proposal in the intensification of the silvopastoral systems, with direct use of the tree legume.

The space arrangement showed a proposition different to that traditionally conducted in the silvopastoral systems, as it shortened in different densities the plantation frame between the furrow and the plant, so the densities can be achieved as those in this study.

The strategy proposed to include a high density level allows modifying the plant structure, and could optimize the biomass production in a silvopastoral system. It should be mentioned that the association of these densities of leucaena with coconut tree, as shade crop, did not affect the biomass production, since the tree legume showed great adaptation capacity to the quality of sun rays in respect to time and photomodulation of its foliage (Somarriba 2004).

Different authors state that the light and temperature proportion affects the growth of young plants, in almost all the botanical components in the ecosystem (Ruiz *et al.* 1989, Shelton and Brewbaker 1994 and Shelton and Jones 1995). However, in this case, the coconut tree shade was gradual due to the sun position, and not pemanent as it was probably in the experiments cited.

The best growth rate values were with 80 and 60 thousand plants/ha and at 100 d of age, but not differing significantly from 60 thousand plants/ha at 85 d, being the first of them different from the rest (table 3). 40

Both, productive rate and water use efficiency were higher with 80 thousand plants/ha at the age of 100 d.

In respect to leaf/stem ratio, it was higher with 40 and 60 thousand plants/ha at the ages of 55, 70 and 85 d (table 3).

Growth and productive rate showed a linear tendency to increase with growth age, showing a decreasing linear tendency with age.

Due to the high biomass production in the treatment with 80 thousand trees/ha, the best efficiency use of consecutive water intake was also obtained in this treatment.

Table 3. Growth rate, leaf-stem ratio and water efficiency use in leucaena with different ages and sowing density

Age (days)	Density (trees/ha) (thousands)	Growth rate (cm/d)	Product rate (kg DM/d/ha)	Leaf/stem ratio	Water eficiency (kg DM/m^3)
100	80	1.38[a]	61.59[a]	2.38[d]	6.84[a]
100	60	1.33[ab]	25.45[bc]	2.86[d]	2.82[b]
100	40	1.22c[d]	16.43[cde]	2.61[d]	1.82[bcde]
85	60	1.30[abc]	21.81[bcd]	4.59[a]	2.06[bcd]
85	40	1.18[bcd]	13.84[de]	4.55[a]	1.30[cdef]
85	80	1.15[bcd]	29.29[b]	3.69[bc]	2.76[b]
70	60	1.08[de]	15.38[cde]	4.64[a]	1.19[cdef]
70	40	0.91[e]	12.20[de]	4.81[a]	0.95[def]
70	80	0.90[e]	29.18[b]	3.64[c]	2.27[bc]
55	60	0.53[f]	15.26[cde]	3.57[c]	0.93[def]
55	80	0.53[f]	22.76[bcd]	3.61[c]	1.38[cdef]
55	40	0.52[f]	10.50[e]	4.27[ab]	0.64[f]
40	40	0.31[g]	9.18[e]	4.54[a]	0.40[f]
40	80	0.31[g]	17.26[cde]	4.53[a]	0.76[ef]
40	60	0.30[g]	14.37[de]	4.57[a]	0.63[f]
ME		0.04	3.08	0.17	0.33
P		***	***	***	***

[abc]Values with different letters in the same column differ significantly at $P < 0.001$***

It is important to mention that the results of this study could be also due to the uniform humidity conditions of the soil, because of the sprinkling support in the establishment and the fertility conditions of the experiment, showing the tree its genetic potentiality. This also corresponds with the increase of the photosynthetic capacity showed in the botanical structure with the time of study, influencing on a higher specific weight of the edible parts of the plant. These variables have been presented in this study. Besides, they agree with the statements of different authors (Farage *et al*. 1998, Ghannoum *et al*. 2000, Muir *et al*. 2001 and Sage 2001), who detailed on the predominant climatic conditions, their capacity for using efficiently the soil humidity and, therefore, the nutrients, the estomatic condition and CO_2 fixation.

It is concluded that the use of high densities of leucaena sowing in coconut shade conditions increased the yields of dry matter and modified positively the edible parts of leucaena in low input conditions for its establishment.

The density of 80 thousand plants/ha of leucaena intercropped with coconut trees is proposed. Its assessment and persistence as a silvopastoral system with cattle is also suggested.

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