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EFFECT OF THE PLANTATION DENSITY IN THE GROWTH AND PRODUCTIVITY OF *Cnidoscolus chayamansa* MCVAUGH (EUPHORBIACEAE)

[EFECTO DE LA DENSIDAD DE PLANTACIÓN EN EL CRECIMIENTO Y PRODUCTIVIDAD DE *Cnidoscolus chayamansa* MCVAUGH (EUPHORBIACEAE)]

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SUMMARY

The plantation density (PD) is a decisive factor in the agronomical resources of cultivation; as such, in this experiment, the effect of the growth and the productivity of the chaya plants were evaluated, as an associated growing in the cedar-lime system, to determine its optimum PD. The chaya plants were positioned at 1.50 x 3.00 m, utilizing cuttings without leaves; associated with young trees (less than 2 years) of *Cedrela odorata* and *Citrus latifolia* in a circular plantation design 'Nelder' of 3154 m^2. Eight PD from 2602 to 3772 plants·ha^{-1} were defined with 10 repetitions. The variables were: rhizogenic potential (RP), growth rate (GR), index of vigor (IV), index of leaf area (ILA) and production of dry biomass (PDB). The results indicated that of the 3046 to 3772 plants·ha^{-1} were found to have the best RP, the ILA (5.44) and PDB (8.48 kg·$plant^{-1}$); even though the IV (1.16) and GR (0.51 cm·day^{-1}) were the best in 2602 to 2647 plants·ha^{-1}. As the primary objective in this specie is the PDB, the PD optimal was 3046 to 3772 plants·ha^{-1}.

Key words: 'Nelder' design; response surface optimization; index of vigor; index of leaf area.

RESUMEN

La densidad de plantación (DP), es un factor decisivo en el manejo agronómico de los cultivos; por ello, en este experimento se evaluó su efecto en el crecimiento y la productividad de las plantas de chaya, como cultivo asociado al sistema cedro-limón, para determinar su DP óptima. Las plantas de chaya se establecieron a 1.50 x 3.00 m, utilizando estacas sin hojas; se asoció con árboles jóvenes (menores de 2 años) de *Cedrela odorata* y *Citrus latifolia* en un diseño de plantación en círculo 'Nelder' de 3154 m^2. Se establecieron ocho DP, de 2602 a 3772 plantas·ha^{-1} con 10 repeticiones. Las variables fueron: potencial rizogénico (PR), tasa de crecimiento (TC), índice de vigor (IV), índice de área foliar (IAF) y producción de biomasa seca (PBS). Los resultados indicaron que de 3046 a 3772 plantas·ha^{-1} fue donde se consiguió el mayor PR, IAF (5.44) y PBS (8.48 kg·$planta^{-1}$); aunque el IV (1.16) y TC (0.51 cm·$día^{-1}$) fueron mayores de 2602 a 2647 plantas·ha^{-1}. Como el objetivo prioritario en esta especie es la PBS, la DP óptima fue de 3046 a 3772 plantas·ha^{-1}.

Palabras clave: diseño 'Nelder'; optimización en superficies de respuesta; índice de vigor; índice de área foliar.

INTRODUCTION

The chaya (*Euphorbiaceae*) is a bush sub-perennial and self-seeding, that grows to a height of 5 m when it is cultivated in subtropical climates, it prospers from 0 to 1000 msnm and requires 650 to 1500 mm of precipitation annually (Stephens, 2009). In Mexico, its principal uses are as a vegetable, forage, and medicine;

being that the leaves are the part used most (Ross-Ibarra and Molina-Cruz, 2002). In spite of having a high anthropocentric value, they lack precise dates of production, due to the fact that its crossbred specie that is found associated with other vegetable components in agroforestry systems (Cuanalo de la Cerda and Guerra-Mukul, 2008).

It is a specie with a high nutritional value (Sarmiento-Franco *et al.,* 2003), the reason for which it is considered an important vegetable in the diet of the Mayan communities in the country (Cuanalo de la Cerda and Guerra-Mukul, 2008). In spite of having a high agronomical potential, its method of production has changed little from prehispanic times; since being a semidomesticated specie, in which its growth and productivity are low (Parra-Tabla *et al.,* 2004); and maintaining a negative relation in relation to the interspecific competency; it's to say, the best plantation density (PD) has less growth (Jose *et al.,* 2004; Parra-Tabla *et al.,* 2004).

A strategy that can increase the growth and productivity is the chaya plants, refers to the management of the PD. The PD is an agronomical factor in the management that influences in the development of the species and refers to the number of established plants in the determined area and has the effect in all the steps of plant development due to the competency for water, solar energy, nutriments and physical space (Mohammed-Nazeeb *et al.,* 2008). The PD can modify the environment, causing an increase or decrease in the growth and productivity (Escalante-Estrada *et al.,* 2008). Favorable management of this factor can optimize the growth space and increase productivity in individual or associated species.

The growth rate (GR), the index of vigor (IV) and the index of leaf area (ILA), can be indicators representing the growth and productivity of a plant (Hunt *et al.,* 2002; Makhabu *et al.,* 2006; Koyoma and Kikuzawa, 2009). The changes to these indicators are determined by the genetic factors, environmental and management. Of the management factors, the PD is what affects those most; its study is important because it has an effect in all the steps of the growth due to the competency effect by water, solar energy, nutriments and physical space (Mohammed-Nazeeb *et al.,* 2008).

The GR is an index that integrates the functioning of various organs of the plant and is referred to the accumulation of dry material by unit of ground area, by unit of time; and it can be expressed in $cm \cdot day^{-1}$ (Hunt *et al.,* 2002). The IV is an indicator of the capacity that the plant has to grow and the strength to develop itself (Makhabu *et al.,* 2006). The ILA refers to the proportion of the area of the leaf to the plant, with respect to the ground surface area (Koyama and Kikuzawa, 2009); serves to evaluate the intensity and assimilation by surface unit, and it is most relevant when you do the analysis of growth (Peil and Gálvez, 2005).

The growth that translates to formation of dry material or biomass can be evaluated as productivity in the distinct phases of the development of a plant. The productivity (biomass and leaf area, principally), refers to the accumulation of dry material by unit of ground area by unit of time (Peil and Gálvez, 2005). The biomass is a vegetable tissue expressed in terms of dry weight, being formed as a product of photosynthesis and the incorporation of nutriments; and can be evaluated as biological productivity in the distinct phases of development (Evert *et al.,* 2008). The work related with agronomical management of the chaya plants are scarce; because of this, the objective of this investigation was to evaluate the effect of the plantation density in the growth and productivity of the chaya plants, as a culture associated in the cedar-lime system, to find an optimum PD.

MATERIAL AND METHODS

Area of study

The experiment was realized from September 2008 to May 2010, in Noh-Bec, Quintana Roo, Mexico (19°06' N, 88°10' W and 11 msnm); the area where the experiment was established presents and annual medium temperature of 25.7 °C, 1562.4 mm of annual precipitation and 1404.3 mm of annual evaporation. The ground is calcareous "Ek-Lu´um" (following the Mayan classification) or the black rendzina soil (following the classification of the FAO-UNESCO); their principal characteristics are: black in color, shallow and fertile (WRB, 2011). During the experiment we took the soil to a depth of 0-30 and 30-60 cm, the values obtained were: 1.13 and 1.15 $g \cdot cm^{-3}$ of apparent density, 6.97 and 6.70 of pH, 30.1 and 32.4 $Cmol(+)kg^{-1}$ of CIC, 4.97 and 3.83 % of organic material, 0.14 and 0.08 % of total N, 19.0 and 24.6 $mg \cdot kg^{-1}$ de P, 0.30 and 0.33 $Cmol(+)kg^{-1}$ of K, for both of the depths respectively.

Vegetable material

Occupying 600 cuttings culinary woody of chaya plants, without leaves, at 40 cm of length and 2 cm in diameter, coming from the top sections of mature and healthy trees in the zone; and in which a indol butyric acid (IBA) was added 1500 ppm plus naphthalene acetic acid (NAA) 200 ppm to promote root growth. The cuttings planted on 3 September, 2011, in a depth of 5 cm directly in the ground, with a distancing of 1.50 m between plants and 3.00 m between lines. They were associated or made to compete inter specifically with young cedar (*Cedrela odorata* L.) and 'Persa' lime (*Citrus latifolia* Tan.), less than 2 years;

established in a 'Nelder' circular design of 3154 m^2 with a variable PD (Figure 1). The experiment developed in local ground conditions; the weed was controlled with applications in the morning with herbicide (Paraquat plus glifosato, 2 $L \cdot ha^{-1}$ every 2 months) in addition to cultural works every 2 months.

Evaluated variables

The treatments were defined with a base in the PD obtained in the area of each circle of 'Nelder' design (Nelder, 1962) to associate the chaya plants with the limes and cedars. The circles 2-9 of each species that occupied the treatments, meanwhile circles 1 and 10 was not used, to prevent the border effect in the area without cedars nor limes to the interior and exterior of the circle. In each variable utilized it showed random of 10 plants for treatment (utilizing a table of lucky numbers), to evaluate 20 months after the transplant, the following:

a) Rhizogenic Potential (RP), is the capacity of the cuttings to generate adventitious roots and form a radical functional system. Considering elements like: percentage of survival of cuttings, percentage of cuttings with roots (extending the complete plant), percentage of cuttings with callus (extending the complete plant), number of roots per cutting (extending the complete plant) and radical length (measuring the more extensive roots by the size of the base roots, utilizing a metric measuring tape).

b) Growth Rate (GR), is estimated with the equation: $GR=[(W_2W_1)/(t_2-t_1)]/S$, where W_2 and W_1: final biomass and start of the complete plant in an interval of time; t_2 and t_1: final moment start of such period; S: area of occupied terrain for the plant (Hunt *et al.*, 2002).

c) Index of Vigor (IV), is calculated by means of the formula: $IV=\beta_0(1-e^{-\beta_1 t})^{\beta_2}$, where β_0: height of plants; β_1: growth rate; β_2: diameter of the crown (the means of the calculations N-S and E-W, made with a metric measuring tape); t: time (Zhao-Gang and Feng-Ri, 2003).

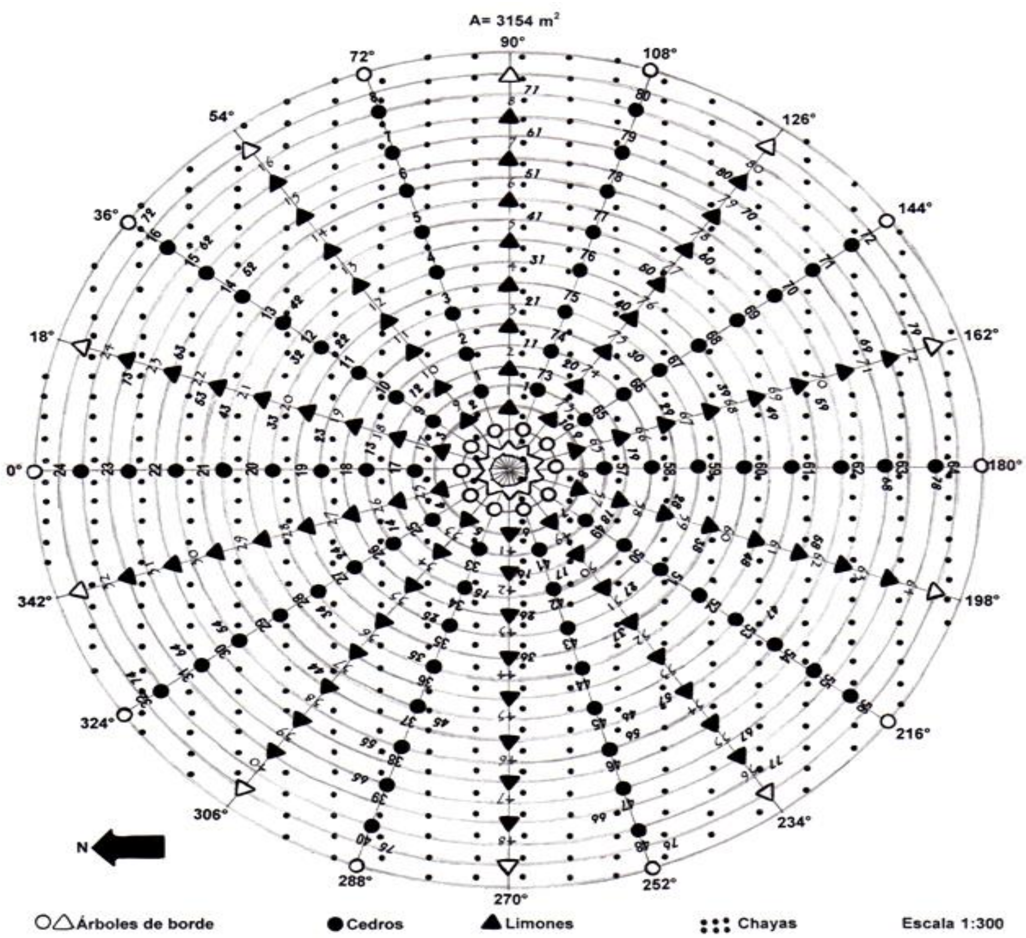

Figure 1. Plantation design in a 'Nelder' circle with interspecific competency and variable plantation density for chaya plants.

d) Index of leaf area (ILA), realizing a destructive model at the end of the experiment, utilizing 20 leaves for treatment, the leaf area (LA) measured utilizing an integrator (Model Li-3000A, Li-Cor Lincoln Nebraska, USA) and later estimated the ILA using the formula $ILA=LA(PD)/10000\ cm^2$, where LA: foliage area per plant (m^2); *PD*: plantation density (plants·m^{-2}) (Garduño-González *et al*., 2009).

e) Production of dry biomass (PDB), calculated with the formula: $PDB=W_2-W_1$, where W_2: final dry weight; W_1: initial dry weight; obtained utilizing a destructive method extending the complete plant (radical system and area portion). The fresh biomass was dried at 60 to 70 °C in a forced air circulation stove (model SL305) until obtaining a consistent weight, in order that the water did not interfere in the results.

Description of treatments and analysis of datum

The experimental unit and observation was a chaya plant, managing eight assigned treatments systemically with 10 repetitions (Figure 1 and Table 1). They found ANOVA´s independent with comparative testing means by the Tukey´s (α=0.05), for a Model of Multiple Optimization in Response Surfaces (Montgomery, 2006); using the software MINITAB 16.

RESULTS AND DISCUSSION

Rhizogenic Potential (RP)

Superimposing the plantation design in a 'Nelder' circle, established cultivation with chaya plants in a rectangular design mark, by which utilizing cuttings culinary woody. The reason for which it was possible to analyze the RP (the capacity to generate adventitious roots) in this growing. In Table 2, observe the statistical difference (α=0.05) in the distinct variables; the highest percentage of survival of cuttings was from 3297 to 3772 plants·ha^{-1} and the least percentage from 2602 to 2647 plants·ha^{-1}. The highest percentage of cuttings with roots was from 2706 to 3772 plants·ha^{-1} and the least from 2602 to 2647 plants·ha^{-1}. For the percentage of cuttings with callus, the highest values were from 2602 to 2647 plants·ha^{-1} and the lowest from 2706 to 3772 plants·ha^{-1}. The greatest number of roots per cutting was obtained from 3046 plants·ha^{-1} and the lowest in 2602, 2889 and 3772 plants·ha^{-1}. The best radical length per cutting was obtained from 3046 to 3772 plants·ha^{-1} and the least lengths from 2602 to 2647 plants·ha^{-1}. The statistical difference counted to the different physiological age of the cuttings, and the interspecific competency and a condition not homogenous to the soil; variation in depth (25 to 50 cm), MO (3.83 to 4.97 %), N (0.08 to 0.14 %) and P (19.0 to 24.6 mg·kg^{-1}).

The best percentage of survival was obtained in chaya cuttings from 3297 to 3772 plants·ha^{-1}, which is acceptable for farm production; and suggests that the PD measurement was diminishing, also affected the survival. Ross-Ibarra and Molina-Cruz (2002) and Sarmiento-Franco *et al.* (2003) indicated that the chaya cuttings easily rooted, not withstanding that they presented a radical slow growth. Statistically there was a difference (α=0.05) in the RP of the chaya cuttings (Table 2), however, it was in the best PD from 3046 to 3772 plants·ha^{-1} where they presented the highest values: up to 97 % survival, 99 % of the cuttings emitted roots and they had lengths of up to 188 cm; in comparison with a less PD from 2647 plants·ha^{-1} where the growth was low. The previous accounts for a better PD due to a better vegetable coverage, that protects the ground loss of humidity and N, contributing to the radical system of development (Petit *et al.*, 2009).

The cuttings that formed callus (up to 4 % maximum), remained latent, without developing roots nor leaves; which does not necessarily indicate they will develop a complete plant except that they will probably begin to decay using up the contents of the stem reserves (Evert *et al.*, 2008), with little to no opportunity to develop due to the fact of the interspecific competency. All of the developing roots of the chaya cuttings, formed in the nodal adjacent cut, probably in the region of the vascular cambium; this agrees with the results obtained in other cultivations such as *Malpighia emarginata* (Rivero *et al*., 2005), *Feijoa sellowiana* (Meng *et al*., 2009) and *Prosopis alba* (Oberschelp y Marcó, 2010).

In spite that cuttings without leaves were used, the auxinas contained in the buds were able to stimulate the formation of roots (Table 2); however, the physiological age of the cuttings and the successful application of IBA 1500 ppm + NAA 200 ppm, was an adequate favorable percentage for rooted cuttings with a good number of roots (up to 28 per cutting); as obtained in other cultivations such as *Malpighia emarginata* (Rivero *et al*., 2005), *Feijoa sellowiana* (Meng *et al*., 2009) and *Prosopis alba* (Oberschelp y Marcó, 2010). In all the treatments, up to 20 months after the plantation, the development the radical system was six times less in comparison with the development of the portion area. This reaffirms that the radical growth of the chaya plants are slow (Sarmiento-Franco *et al.*, 2003); and that an adequate availability of soil nutriments, is favorable to observe less extensive radical systems (De Dorlodot *et al*., 2007).

Table 1. Treatments in the 'Nelder' design for chaya plants.

N	cedar	lime	chaya	
	PD (plants·ha^{-1})	PD (plants·ha^{-1})	DP (plants·ha^{-1})	Treatment (plants·ha^{-1})
1¶	1134	1666	2222	
2	691	859	2222	T_1 = 3772
3	497	578	2222	T_2 = 3297
4	388	436	2222	T_3 = 3046
5	318	349	2222	T_4 = 2889
6	270	292	2222	T_5 = 2784
7	234	250	2222	T_6 = 2706
8	206	219	2222	T_7 = 2647
9	185	195	2222	T_8 = 2602
10¶	167	176	2222	

N (number of circles). PD (plantation density in the circle).
¶ Circle used as a border.

Table 2. Rhizogenic potential in cuttings culinary woody of the chaya plants, 20 months after plantation in a black rendzina soil (Ek-Lu´um).

Treatments (plants·ha^{-1})	Survival of cuttings (%)	Cuttings with roots (%)	Cuttings with callus (%)	Number of roots for cutting	Radical length (cm)
2602	86 c	96 b	4 a	24 c	104 c
2647	88 c	96 b	4 a	26 b	112 c
2706	92 b	98 a	2 b	25 b	125 b
2784	92 b	99 a	1 b	25 b	138 b
2889	93 b	99 a	1 b	24 c	152 b
3046	94 b	99 a	1 b	28 a	164 a
3297	97 a	98 a	2 b	26 b	176 a
3772	97 a	99 a	1 b	24 c	188 a
CV (%)	12.33	10.74	11.79	16.42	12.95
MSD	1.86	0.71	0.42	0.63	3.37

CV: coefficient variation, MSD: minimum significance difference. Means with the same letter inside each column are statistically equal in accordance with the Tukey´s formula (α=0.05).

Vegetative Growth

At 20 months after plantation, the chaya plants had a maximum GR of 0.51 cm·day^{-}1, at 2602 plants·ha^{-1}; but if to establish a better PD to this, their growth would diminish from 0.04 to 0.09 cm·day^{-1} (Figure 2). Another form to explain the patterns of growth, is measuring the dynamic of the PD base to the dates, considering how PD low (from 2602 to 2706 plants·ha^{-1}), how PD intermediate (from 2784 to 2889 plants·ha^{-1}) and how PD high (from 3046 to 3772 plants·ha^{-1}). Of the 0 to 8 months the chaya plants showed a lineal growth in all the PD; from 8 to 12 months the growth increase in PD intermediate and high, and in low PD maintained constant; from 12 to 16 months increase in PD high and low, and maintained constant in PD intermediate; from 16 to 20 months increase in PD low, intermediate and high (Figure 3).

The GR was sigmoidal, in which coincides with the other obtained cultivations such as: *Malus domestica* (Costes *et al*., 2006) and *Solanum tuberosum* (Flores-López *et al*., 2009); it is said, start at the origin, advance slowly augment in exponential form (in proportional relation with the size of the organism), maintain calm and augment again (Figure 3). This means that there was an alternation in the growth, in which, meanwhile the portion area found in active growth, the radical system maintains calm and viceversa (Costes *et al.*, 2006). The growth of the plants not only depends on the absorption and transformation resources in biomass, but also that the plants and resources are fixed relatively in the space (Hunt *et al.*, 2002). The GR is not limited only by the amount of water or the availability of nutriments, but also by the solar energy that the foliage was able to intercept (Jose *et al*., 2004). From 2602 to 2647 plants·ha^{-1} the competency was more adequate for this variable, it's to say, there was a balance of water, solar energy, nutriments and physical space, that permitted the plants to express their best genetic potential.

In Figure 2, observe that from 2602 to 2647 plants·ha^{-1} the chaya plants had a maximum IV (1.16), in these PD the ILA and the PDB was less; the chaya plants, from 2706 to 3772 plants·ha^{-1} reduced its vigor from 0.14 to 0.28; similar to its response to its GR. Meanwhile higher is the IV, representing a major growth in a determined time (in this case, 20 months after plantation) (Zhao-Gang and Feng-Ri, 2003).

In Figure 4A, presents another scenario for the PD management; where the best GR (0.51 cm·day^{-1}) and IV (1.16) was found at 2602 plants·ha^{-1}; the tendency for these variables shown from 2706 to 3772 plants·ha^{-1}; the growth and vigor was less. In all, the PD and the 20 months after plantation, the values that expressed the IV in the chaya plants: plant height (from 1.70 to 2.00 m) and the volume of crown (from 0.50 to 1.70 m^3) were referred good health and appearance of the plants; because the IV was a confident indicator to measure vegetable growth. It indicated, in addition, an excellent adaptation of the chaya plants to the environment conditions of the zone (Cuanalo de la Cerda and Guerra-Mukul, 2008).

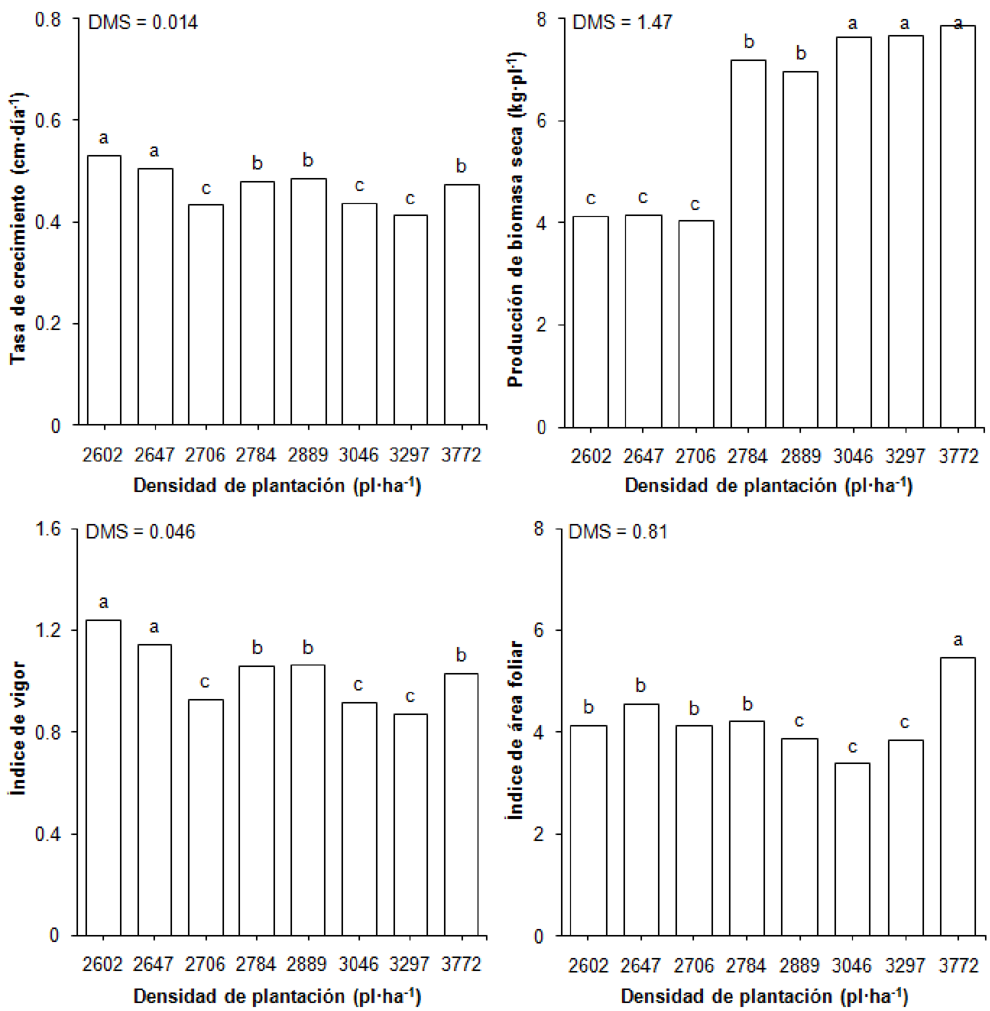

Figure 2. Growth rate, index of vigor, index of leaf area and production of dry biomass in the chaya plants, at 20 months after plantation. Bars with the same letter do not differ statistically between itself. SMD: minimum significant difference is at α=0.05.

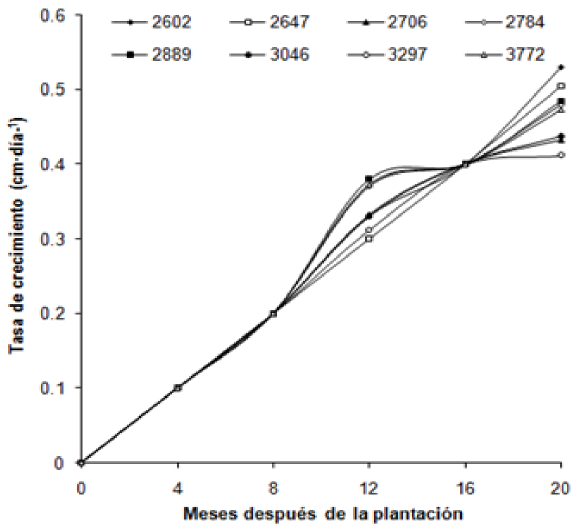

Figure 3. Sigmoidal rhythmic growth in chaya plants to different plantation density.

Biological Productivity

In Figure 2, observe a maximum ILA of 5.44 to 3772 plants·ha^{-1} in which we can see a better proportioned PDB. As such, a better ILA, better PDB, as documented by Garduño-González *et al.* (2009). The productivity was best from 3046 to 3772 plants·ha^{-1}, because the competitive interactions for water, solar energy, nutriments and physical space were minimized by the complementary (Forrester *et al.*, 2006; Petit *et al.*, 2009). In this sense, Forrester *et al.* (2006) and Garduño-González *et al.* (2009) affirmed that the total productivity by surface unit increases when the species is found associated, diminishing its efficiency in mono-cultivation systems; the reason by which, to associate the chaya plants with the cedars and limes, the biological productivity was high.

In Figure 4C, observe that the chaya plants, demonstrated a maximum ILA (5.44) at 3772 plants·ha^{-1}; with a positive lineal tendency toward a better PD, the ILA values diminished in proportion to making the PD, meanwhile, the productivity can decrease in function to the difficulty to obtain resources. From 2602 to 2442 plants·ha^{-1} the productivity for hectare was less, because it didn't occupy all of the available area, as such, the productivity for unit of area was inferior to the maximum productivity possible.

The fact to obtain a better ILA at 3772 plants·ha^{-1}, also indicate competition (remember that the chaya plants are associated with cedars and limes), which is not necessarily conductive to a less PDB (Figure 2) (Jose *et al*., 2004; Koyama and Kikuzawa, 2009). The fact is that the best productivity also is to obtain a measurement of interspecific ecological balance, such as in the below ground as in the above ground (García-Barrios and Ong, 2004).

In Figure 2, observe a maximum PDB (8.48 kg·plant^{-1}) from 3046 to 3772 plants·ha^{-1} which indicates that the foliage in these PD´s were more efficient in the photoassimilation, demonstrating a better photosynthesis capacity, given that the PDB is functioning with the photosynthesis, the respiration and conversion efficiency of carbohydrates to dry material (Peil and Gálvez, 2005; Koyama and Kikuzawa, 2009). The prior results coincide with those obtained in *tuberosum* (Flores-López *et al.*, 2009), the same as in *Phaseolus vulgaris* associated with *Helianthus annuus* (Garduño-González *et al.*, 2009). Given that from 2602 to 2706 plants·ha^{-1} there presented a point of photosaturation in which no more biomass was produced even though the most solar energy exist.

The fact that the PDB for superficial unit in major PD at 3422 plants·ha^{-1} has not been incremented in significant form, indicates that the competency between plants was not able to be improved in the supervised capacity and efficiency in the use of resources from the soil (water and nutriments, principally) (Forrester *et al.*, 2006). Without considering that the stems, leaves and dead roots, are incorporated consistency to the soil, to maintain and increment its fertility (Petit *et al.*, 2009). In the cuttings, the initial growth in the portion area was rapid and the roots were slow, because of this the leaves must grow until the second year without exceeding the defoliation more than 50 %, to guarantee an adequate vegetable growth (Sarmiento-Franco *et al.*, 2003).

In Figure 4B, presents another scenario for the PD management; at 20 months after plantation the best PDB (8.48 kg·plant^{-1}) observed at 3422 plants·ha^{-1}, the tendency indicates that in the measurement the PD diminished, this value also lowered, which indicates that a competency was less than the availability of resources from the soil. In relation to this, Geyer (2006) encountered that the growth space affects the PDB in species such as: *Acer saccharinum*, *Robinia pseudoacacia*, *Populus deltoides*, *Gleditsia triacanthos* and *Ulmus pumila;* where the PBD by superficial unit was better in the first two years. However, after nine years the plants were losing vigor, questioning the accumulated economic cost for plantations in high PD.

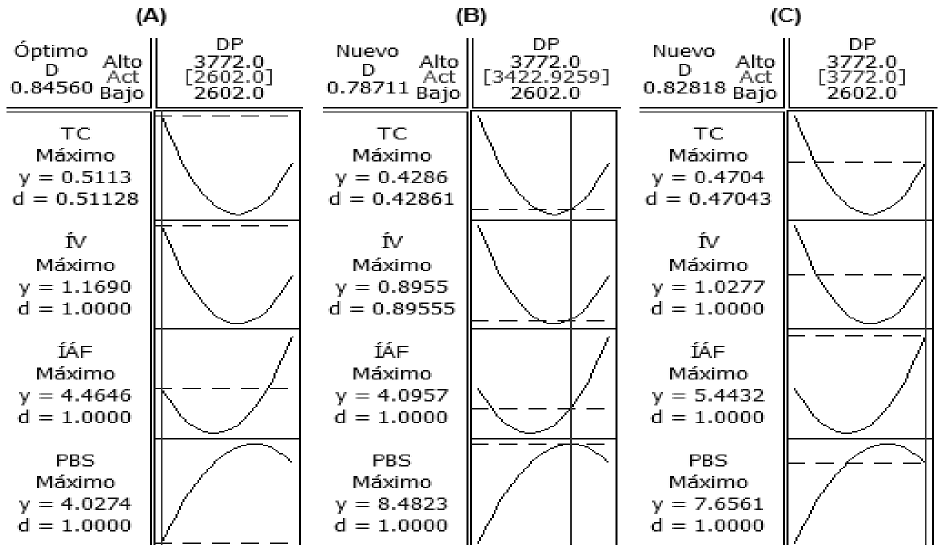

Figure 4. Scenarios with maximum values for the growth and productivity in chaya plants, in (A) growth rate (GR) and the index of vigor (IV), in (B) production of dry biomass (PDB), in (C) index of leaf area (ILA); at 20 months after plantation.

The ILA and the PDB are the two fundamental structural parameters to describe the crown of a tree in relation to the limiting factors (principally water, solar energy and nutriments) (Geyer, 2006). The PDB must be considered as the captured product for the resource most limited, and the efficiency in which the captured resource converts in biomass (García-Barrios and Ong, 2004). The competency for solar energy and its impact in the PDB, can be measured managing the PD, and the understanding of the processes of competency and the completion of the crowns (García-Barrios and Ong, 2004; Jose *et al.*, 2004).

In the search of an optimum PD, and considering such growth objectives and the productivity, a better GR and IV is obtained at 2602 plants·ha^{-1} is not conducive to obtain the same PD a better ILA and PDB (Figure 4). However, being the PBD (particularly the foliage of the portion area) primary objective in the profiting of the chaya plants (Ross-Ibarra and Molina-Cruz, 2002; Stephens, 2009), the optimum PD is defined in function from this variable, as such the optimum interval was from 3046 to 3772 plants·ha^{-1}.

CONCLUSION

The vegetative macropropagation of the chaya plants is measured factually the rooting of cuttings in the apical and middle section of mature bush; being the number of roots and the radical length, the components more important in the rooting. The growth and productivity of the chaya plants are influenced strongly by the plantation density, because to surpass from 2602 to 3772 plants·ha^{-1} the intraspecific value changes in response to the interspecific competency; as such, from 2602 to 2647 plants·ha^{-1}, was where the best growth rate was observed and index of vigor; meanwhile from 3046 to 3772 plants·ha^{-1} was where the best rhizogenic potential expressed, index of leaf area and production of dry biomass. As such, these final densities are the optimum to obtain the best productivity in the chaya plants.

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