

Forced production of mango (*Mangifera indica* L.) planted at high density (278 trees ha⁻¹) in the growth period.

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Abstract

A mango trial was established in 1996 using five-year-old trees. Cultivars Haden, Tommy Atkins, Springfels and Edward grafted on «Criollo» were planted at 6x6 m (278 trees ha⁻¹) to evaluate the pruning effect at 2m height, the Paclobutrazol (PBZ) effect when applied to the soil (2.5 g ai per tree) and flowering promoter potassium nitrate (KNO₃), at 6% on the vegetative growth and yield of the mango cultivars. The treatments were: Checker (T), T + PBZ, Pruning (P) and P + PBZ. P + lateral branches of a radius of 2 m (P+L) and P + pruning of internal primary branches (P+E). The studied variables were increase of canopy volume (ICV), yield (kg tree⁻¹) and productive efficiency (kg tree m⁻³). It was found that the largest pruning increases the canopy volume, with a concomitant reduction of fruit yield, due to the moderate pruning increase significantly the productive efficiency. Yields (t ha⁻¹) for the four cycles 1996-2000, for the different treatments were: 19.29 T; 24.6 T+PBZ; 19.7 P; 19.6 P+PBZ; 18.1 P+E and 13.2 P+L. These yields were higher (>200%) than the one reached by low tree density system (69 tree ha⁻¹) in the same time. In general, the results showed that in the «Growth Period» of fruit trees, characterized by a large volume growth in the productive life cycle of the tree is the most critical to be controlled to reduce the free height. If we consider that 90% of the country fruit production came from small and medium size growers, the use of a high tree density system should provides an improvement of the income of these peoples. **Key words:** *Mangifera indica*, regulator, pruning, yield.

Introduction

Mango constitutes one of the most nationally spread fruits with 8650 ha⁽¹⁾; which participation on the international market has been

increasing in the last years, reaching in 1999 around 5 thousand exported tons, especially to European countries. However, the low average

production level (from 12 to 15 t ha⁻¹) when plantations reach 12-14 years old, will be a factor that in short or mid term will limit the competitiveness on the market, being one of the causes that motivates this limitation the use of patterns and crown characterized of inducing a high vegetative vigor, that forces the employment of low population densities by hectare (2, 9).

Most of the commercial crown employed in the country are monoembryonic of sub-tropical origin, that express a high vegetative vigor under high temperature conditions, which besides of affecting the flowering process, makes difficult the phytosanitary controls and harvest, negatively influencing the crop productivity (2, 9, 10, 29). Therefore, the cultivar selection with low vegetative vigor in high temperatures, 25°C to 30°C of daily maximum, and the use of physical and/or chemical procedures to control the look or size of the tree, constitutes important strategies on the productivity improvement of mango in the tropic (15, 20, 30).

The shape of the mango tree was defined by Verheij (28), as a poliaxial specie with a normally rhythmic growth; and Avilán (1, 2) in plantations with low densities (69 plants ha⁻¹) and employing the fructification index (fruits number by m² of forage), established, through the variation of productive efficiency, four periods on the productive life's cycle

of the plant. The growth period, that extends from 2 to 8 years old, is characterized by a marked increased of the foliar area or forage, and the beginning and gradual increment of the fruit number. The initial low fructification index generally improves with the age of the plant.

The period of total production, correspondent to the phase where is little relation between the increment of crown volume, and the produced fruits number, initiates from around 9 years old, and extends until 14-15 years old; and during this time, the highest fructification indexes are obtained. The production period, characterized by a very little increase of the forage, and a tendency to keep the production levels of fruits, reached during the previous period, or with very few increments. However, the fructification index gradually reduces with the time. It means, the productive efficiency of the plant decreases progressively because the increments in the foliar area do not correspond with the production increments of fruits. This period happens from 16 to 28 years old or more. The withering period, is the beginning of the final phase and is characterized by a scarce increase of the forage, and the market reduction of yields. The index values of fructification are low. This phase happens once passed 30 years old or more.

The orchard yield is associated with population, and density modifies

¹⁾Venezuela, 2000. Estadísticas Agropecuarias. Caracas. Ministerio de Producción y Comercio. 5 p

the development pattern of the plant. The size control of the tree must be done on the implementation of high densities in order to reduce the productive efficiency lost, by the auto-shady and the competence between the adjacent plants. Between the alternatives are, the employment of dwarf patterns or pattern crown combinations that would induce the low look, grafting with short height and double grafting; likewise, the pruning use and the application of growing regulators and flowering inductors (7, 15, 20, 22). The isolated or combined application of these techniques using several ways of

plantations in different cultivars, have fought with the negative effect of pruning and have significantly incremented the production, without affecting the fruit qualities (11, 15, 16, 17, 18, 21, 23, 27).

In this research are presented the employed results of different types of pruning and the application of a growing regulator (paclobutrazol) to control the trees size, and the effect on behavior and the production of four cultivars of mango of commercial interest that differ in the vegetative vigor during the growing period, sowed in high density (278 plants ha⁻¹).

Materials and methods

On the experimental field of the National Center of Agronomy Research (CENIAP-INIA) located on the north of the country (10°17' N, 67°37' W), characterized as Dry Tropical Forest, that has as general climatic limits a precipitation between 850 and 1000 mm annually, a mean annual temperature between 24 to 26°C, located in an elevation of 450 msnm and soils with good physical conditions of mean natural fertility, classified on the Entisol order (13), an essay was carried out from 1996 when trees were five years old, until they were nine years old, sowed in a distance of six meters between them (278 pl ha⁻¹) of Haden, Tommy, Atkins, Springfels and Edward cultivars grafted on a «Criollo» pattern inductor on short look (3); to evaluate the pruning effect in different intensities and a growth

regulator on the vegetative development and fruit production.

The different pruning modalities (table 1) were: the elimination of the superior part of the crown (topping) in two meters of height from the soil, the cut of the lateral bunches extremes in a radius of 1.8 m from the plant's stem; which were done at the beginning of each annual production cycle; while the sorting of 1 or 2 primary bunches eliminated formed the base or insertion point only at the beginning of the essay. In all done cuts, a healing was applied.

The employed growth regulator was Paclobutrazol (cultar), which application to the soil was done a month after the harvest, an amount of 2.5 g ia was used by plant. The product was diluted in three liters of water as was scattered around the stem in a distance from 1m to 1.5 m

Table 1. Type of prune applied to four mango cultivars.

Type of prune	Description
T	Free growth. Without prune at 2 m height from the soil and without application of a growth regulator.
T + PBZ*	Free growth. Without prune at 2 m height from the soil and with application of a growth regulator Paclobutrazol (PBZ)
P	Prune at 2 m height from the soil and without application of a growth regulator.
P + PBZ*	Prune at 2 m height from the soil and with application of a growth regulator Paclobutrazol (PBZ)
P + E	Prune at 2 m height from the soil, with sorting of 1-2 main branches from the base, and without application of a growth regulator.
P + L	Prune at 2 m height from the soil, with cuts of the lateral branches in a ratio of 1.8 m from the trunk, and without application of a growth regulator.

PBZ*: Growth regulator Paclobutrazol.

of the tree. As a flowering promoter for all the essay's population, the potassium nitrate (KNO_3) was applied at 6%, five months after have pruned; considering that pruned and unpruned buds when are five years old are able to be inducted to have flowers.

On the field essay was employed a plot design 4x6 on a totally randomized design which factors were constituted by cultivars and types of pruning; which generated a total of 24 treatment combinations, each one with three replications. Each experimental smallholding had a tree. Considering that an annual production cycle initiates in July, and ends in June of the following year; the studied variables were: annual volume increment of the crown (IVC)

measured by the difference between the initial volume determined in the moment of the treatment application at the beginning of each cycle, and the final volume when the harvest was done, employing the following formula: $(4/3)pr^2(1/2)h$, where; h is the plant's height and r is the crown's radius. Yield (PF) was established by the fruits weight of each tree. The productive efficiency (EP) was determined, relating yield (PF) and volume (m^3) of the crown at the end of each annual production cycle.

On each production cycle a variance analysis was done. Subsequently, the variance analysis combined in the time was done, considering the annual production cycles as sub-smallholdings and the main smallholdings constituted by

cultivars and types of pruning (25). Means separation was done with the Tukey test with a signification level of mistake type I of $p=0.05$ (24). Previously, the normal estimates were tested (Shapiro-Wilk test), homocedasticidad (Bartlett test), randomized (Mean test), addition (Tukey test) and autocorrelation (Durbin-Wartson test) (26) in IVC, PF

and EP variables. These tests allowed proving that these variables presented normal distributions, with variation coefficient between 30 to 35%. These values are common of crop of everlasting fruit bearing of arboreal type. In order to check the variation coefficients the transformation of square root was used $y_t = \sqrt{y_i + 0.5}$

Results and discussion

Annual increments of the crown volume (IVC)

The statistical analysis of IVC showed highly significant differences (table 2) for: cultivar (C), type of pruning (TP), reproductive cycle (CP) and the simple interaction TP x CP and significant differences for the triple interaction C x TP x CP. Mango's tree is characterized by a continuous increment of the foliar area in all the productive life, but during the growth period the estimates is the highest in relation to posterior periods, and intensity is associated to the vegetative vigor of the cultivar (2). Means comparison for IVC between C (table 3) allowed the establishment of three homogenous groups. The first one constituted by the Haden cultivar, the second one by Edward and Tommy Atkins, all characterized by a high vegetative vigor; and finally, Springfels of low vigor, which gives a tree a short look (22).

In the CP (table 3) reduces the annual IVC, no matter the cultivar, because the growth estimate is lower at the same time that trees increase the age (2). The determined IVC on

1999-2000, when trees were six years old; which corresponded to the described growth period inside the productive life's cycle of the plant (2).

TP (table 3) influences the magnitude of the annual IVC that normally occur in trees during each productive cycle, establishing significant differences between trees in free growth with or without the application of the growth regulator (T+PBZ and T). Pruned trees tend to regenerate the eliminated forage, in order to restore the balance that existed prior to the application of treatments, between the radical system and the aerial part (16); and consequently, in higher pruning density and in higher vegetative development. The growth regulator PBZ, induced a lower growth estimate, even though it is considered that the applied doses (2.5 g i.a. by plant) for the vegetative vigor that characterizes most of cultivars, should had been higher (6).

The CP x TP interactions showed significant differences and C x TP x CP interactions also showed significant differences (table 3),

Table 2. Means table and their meaning, generated for variables: increase of the annual crowns volume (IVC), fruits weight by plant (PF) and productive efficiency (EP). Period from 1996 to 2000.

Variation source	Square means					
	GL	IVC	P	PF	EP	P
Cultivar (C)	3	22.93	0.0002	133.66	2.08	0.0000
Type of prune (TP)	5	37.54	0.0000	42.09	0.37	0.0004
C × TP	15	3.56	0.2958	10.97	0.10	0.1313
Error a (C × TP × R)	48	2.94		11.51	0.07	
Production cycle (CP)	3	10.62	0.0000	278.06	8.59	0.0000
C × CP	9	1.29	0.4531	11.75	0.08	0.0023
TP × CP	15	10.44	0.0000	8.20	0.09	0.0002
C × TP × CP	45	1.94	0.0418	3.87	0.04	0.0563
Error b (CP×R×C×TP)	144	1.31		2.74	0.03	
TOTAL	287	3.23		10.31	16.10	
Means		40.0		71.7	0.94	
CV (%) Error a		28.2		43.0	22.3	
CV (%) Error b		18.8		21.0	14.6	

P: Probability of calculated F>tabulated F

Means squares and variation coefficient were estimated after the transformed values, and means were estimated after the non transformed.

Table 3. Means comparison of the IVC of the C x TP x CP interaction.

Cultivars	Production cycles				Means
	1996-1997	1997-1998	1998-1999	1999-2000	
Haden	520.92 ^a	46.79 ^a	50.14 ^a	46.87 ^a	49.181 ^a
Edward	45.91 ^{ab}	42.25 ^a	43.58 ^{ab}	34.76 ^{ab}	41.624 ^b
Tommy Atkins	44.20 ^{ab}	39.03 ^a	36.55 ^b	26.49 ^b	36.568 ^{bc}
Springfels	35.75 ^b	36.00 ^a	30.31 ^b	28.05 ^b	32.529 ^c
Prune type					
T	45.40 ^a	20.76 ^b	21.94 ^b	46.89 ^a	33.75 ^b
T + PBZ	46.27 ^a	16.33 ^b	32.93 ^{ab}	8.45 ^a	26.00 ^c
P	44.42 ^a	54.86 ^a	49.81 ^a	36.51 ^a	46.40 ^a
P + PBZ	40.94 ^a	47.23 ^a	44.79 ^a	34.15 ^a	41.78 ^{ab}
P + L	38.91 ^a	52.25 ^a	45.00 ^a	37.6 ^a	43.45 ^a
T + E	52.23 ^a	54.65 ^a	46.42 ^a	40.63 ^b	48.48 ^a
CP means	44.7 ^a	41.0 ^{ab}	40.0 ^{ab}	34.0 ^b	

Values with different letters in the same column indicate significant differences at 5% T witness, PBZ paclobutrazol, P prune, E branches sorting, L cut of lateral branches.

indicating that with the tree's age increment the response to the intervention has been done less market. This tendency allows to foresee that the plant's intervention to control the size of the tree in the following periods, which practice is essential in the handling of high density plantations to reduce competence by light (11, 12, 16, 18, 21, 29), could be of less intensity and frequency.

Yields (PF)

The statistical analysis of PF (table 2) established highly significant differences on the main effects of C, TP and CP, and significant differences for the simple interactions: C x CP and TP x CP. In CP, Springfels and Tommy Atkins were the most productive, followed a decreasing order by Haden

and Edward (table 4), which agrees with the observed behavior of these cultivars all the way of the productive life's cycle in the collection of the CENIAP (5), and specially with the referent to the Edward that presented the lowest yields. Variations between consecutives CP were characterized as an alternation, independent of the yields increments, associated to the age of the plant and of the cultivar. The correspondent PF to the production cycle 1998-1999, was significant superior to the one obtained during the 1997-1998 cycles that proceeded and the 1999-2000 cycles that followed. Generally in mango, after a cycle of huge harvest follows one cycle with low production (22).

In TP, means comparisons (table 5) allowed the establishment of three

Table 4. Means comparisons of PF and C, and the C x C interaction.

Cultivars	Annual cycle of production				Efecto C
	1996-1997	1997-1998	1998-1999	1999-2000	
Springfels	67.0 ^a	57.4 ^{ab}	154.3 ^a	83.6 ^a	90.6 ^a
Tommy Atkins	72.1 ^a	81.8 ^a	131.5 ^{ab}	69.2 ^{ab}	88.7 ^a
Haden	49.5 ^{ab}	18.3 ^c	111.4 ^b	60.8 ^b	60.0 ^b
Edward	24.3 ^b	28.5 ^{bc}	86.1 ^b	51.3 ^b	47.6 ^b
Effect CP	45.4 ^c	38.9 ^c	112.9 ^a	62.9 ^b	

Values with different letters in the same column indicate significant differences at 5%

groups. The first one is constituted by T+PBZ and the witness (T), the second group by P+PBZ, P and P+E; the third by P+L. The previously described order of the group corresponds to the inverse of the determined for the annual IVC (table 3). Mango belongs to the type of plant, where it is frequent that actions that stimulate growing do it at the mercy of flowering and fructification (12, 29). Between the most severe TP, P+E and P+L, was presented the lowest yields.

Whiley *et al.* (29, 30) determined that the increment on the vegetative development reduces the concentration of the starch reserves in the plant, and that high concentrations of starch are associated with flowering and productivity of mango.

The average yields by plant (table 5) of the essay are inferior to the considered as «Adequate» (2) for trees with ages around five to nine years old, established in low density

Table 5. Means comparisons of PF and TP and the TP x CP.

Prune types	Annual cycle of production				Efecto TP
	1996-1997	1997-1998	1998-1999	1999-2000	
T + PBZ	61.3 ^a	63.8 ^a	153.0 ^a	76.8 ^{ab}	88.7 ^a
T	72.4 ^a	44.2 ^a	130.0 ^{ab}	100.3 ^a	86.7 ^a
P + PBZ	61.7 ^a	54.0 ^a	106.0 ^{ab}	62.9 ^b	71.2 ^{ab}
P	51.8 ^{ab}	38.9 ^a	141.5 ^a	51.2 ^b	70.8 ^{ab}
P + E	48.1 ^{ab}	41.9 ^a	113.3 ^{ab}	57.0 ^b	65.1 ^{ab}
P + L	24.0 ^b	36.3 ^a	81.4 ^b	49.1 ^b	47.7 ^b
CP effect	45.4 ^c	38.9 ^c	112.9 ^a	62.9 ^b	

Values with different letters in the same column indicate significant differences at 5%. T witness, PBZ paclobutrazol, P prune, E branches sorting, L cut of laterals branches.

(69 plants ha⁻¹). However, it represents for a population of 278 trees ha⁻¹, yields for the different evaluated TP pf 19.29 T, 24.6 T+PBZ; 19.7P; 19.6 P+PBZ, 18.1 P+E and 13.2 P+L, t ha⁻¹ respectively; which surpass in 200% yields of 7.5 and 8.5 ha⁻¹ which are obtained on commercial bearings of similar age in the country, where the traditional system of 69 plants ha⁻¹ (2, 6) is employed.

Productive efficiency (EP)

The statistical analysis (table 2) of EP allowed establishing highly significant differences for C, TP, CP and C x CP and TP x CP interactions. Edward and Haden cultivars, characterized by a high vegetative vigor, presented the lowest efficiency (table 6), which agrees with the said by Cull (12) and Whiley *et al.* (29, 30). The excessive vegetative development that characterizes the monoembryonic cultivars in the tropic, negatively affects the flowering process and therefore, the productivity of the plant. Springfels cultivar, characterizes by a short appearance; as well as Tommy Atkins with low annual IVC or vegetative vigor (table

3) presented the highest productive efficiency. The C x CP interaction (table 6) evidences the tendency to improve EP with the increase of the trees' age, independently of the production, due to annual IVC tend to be lower (table 3) and PF tends to increase (table 4).

In TP, means comparisons allowed the establishment of three groups (table 7), the first one constituted by P+PBZ, the second by P, P+E and T+PBZ, the third by P+L and the witness (T). The removal of the superior part (topping) at the time that increases the interception and light distribution through the profile of the crown, it improved productivity (23). TP with intervention of the plant, excepting P+L, where lateral cuts induced a market vegetative development, presented the highest fructification indexes during the essay, and T in free growing was characterized by a continues lost of EP. This proves, that besides it is required the control of the tree's size to improve EP, it must be also considered this control on pruning, besides the employed severity or

Table 6. Means comparison of EP on the C x CP interaction.

Cultivars	Annual cycle of production				Efecto C
	1996-1997	1997-1998	1998-1999	1999-2000	
Springfels	1.08 ^a	0.82 ^a	2.20 ^a	1.22 ^a	1.33 ^a
Tommy Atkins	1.06 ^a	1.07 ^a	1.71 ^a	1.08 ^a	1.23 ^a
Haden	0.52 ^b	0.19 ^b	1.08 ^b	0.63 ^b	0.60 ^b
Edward	0.33 ^b	0.32 ^b	1.05 ^b	0.58 ^b	0.57 ^b
Efecto CP	0.75 ^d	0.60 ^c	1.51 ^a	0.88 ^b	

Values with different letters in the same column indicate significant differences at 5%

Table 7. Means comparison of EP and TP and the TP x CP interaction

Prune type	Annual cycle of production				Efecto TP
	1996-97	1997-98	1998-99	1999-2000	
P + PBZ	1.10 ^a	0.92 ^a	1.82 ^{ab}	1.20 ^a	1.26 ^a
P	0.72 ^{ab}	0.52 ^{ab}	2.07 ^a	0.90 ^{ab}	1.05 ^{ab}
P + E	0.69 ^{ab}	0.59 ^{ab}	1.65 ^{abc}	0.97 ^{ab}	0.97 ^{ab}
T + PBZ	0.82 ^{ab}	0.68 ^{ab}	1.37 ^{bcd}	0.69 ^b	0.89 ^{ab}
P + L	0.43 ^b	0.49 ^{ab}	1.21 ^{cd}	0.89 ^{ab}	0.75 ^b
T	0.73 ^{ab}	0.39 ^b	0.98 ^d	0.59 ^b	0.67 ^b
CP effect	0.75 ^c	0.60 ^c	1.51 ^a	0.88 ^b	

Values with different letters in the same column indicate significant differences at 5% T witness, PBZ paclobutrazol, P prune, E branches sorting, L cut of lateral branches

intensity grade; the use of a growth regulator and a flowering promoter to control or minimize the response of the plant.

After a severe pruning, the fast vegetative development besides reducing the food reserves of the tree influences the quantity of ripe leaves present on the tree so it will be insufficient to induce the floral stimulus when the environmental conditions are propitious for flowering (19) affecting the flowering process, and therefore the production of fruits. The application of PBZ when inhibiting the biosynthesis of

gibberellins (14), besides creating conditions for the accumulation of carbohydrates, propitiates a reduction of the vegetative growth when reducing the elongation and cellular division, which allows the existence of a greater proportion of ripe leaves, where the inductor substance of the non identified flowering is synthesized. The unripe leaves are rich in flowering inhibitors (8, 14, 16, 19). Tome and Bondad (27) determined that KNO₃ combined with PBZ, results to be 80% more effective than the isolated application to promote flowering.

Conclusions

TP have an influence on the magnitude of the annual IVC, establishing highly significant differences between those influenced by the prune (P, P+PBZ, P+L and P+E) and those with free grow and without the application of PBZ

(T+PBZ and T).

The TP x CP interaction of the annual IVC was highly significant, indicating that the response of the plant to the interaction or prune gets lower at the time that increases the age of the trees.

Springfels and Tommy Atkins cultivars with short or intermediate look respectively, were significantly the most productive, followed on a decreasing order by Haden and Edward characterized by a high vegetative vigor.

TP negatively influenced the production, and the lowest PF occurred where the intervention was

more severe (P+L and P+E).

Trees with free growth without the application of PBZ (T) or with an excessive size's control (P+L) had the lowest EP.

The moderated intervention of the topping and the use of PBZ, on an isolated or combined way significantly improved EP. P+PBZ and P had the higher EP.

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