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# RESPONSES OF 10 YEAR-OLD CACAO TREES (*Theobroma cacao* L.) TO DIFFERENT THINNING AND FERTILIZER TREATMENTS

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SUMMARY

Five thinning treatments were tested on 10-year-old cacao hybrids (UF x amazonic clones) situated at "La Lola", CATIE's farm in the "Atlantic zone" of Costa Rica. Super-imposed on the thinning treatments were two levels of fertilizer applications, 1,500 kg/ha and 2,250 kg/ha of 18:10:6, respectively. The statistical design was a split-plot.

This work seeks to evaluate different plant-densities and distributions, as well as the responses to the levels of fertilizer application.

The original planting distances were 2 x 2 m and 2 x 3 m in the designated sections 6 and 8, respectively.

Responses to the treatments were made based on yield of wet cocoa, tree-girth at 0.3 m from the soil, jorquette-height, fresh-weight of chupon, the number of chupons produced and the incidence of *Phytophthora* infection, principally.

Yield of cocoa was evaluated fortnightly while the vegetative features were taken at certain time intervals.

In Section 6 (2 x 2 m), thinning out of 50 per cent of the weak trees produced the greatest yield, while in Section 8 (2 x 3 m) it is best not to practice thinning at all. Generally, the lower level of fertilizer application (1500 kg/ha) resulted in greater yields of cocoa per hectare.

On an individual tree basis, treatments with looser plant-densities, produced more cocoa, had greater annual diameter-increases and produced more chupons than treatments with greater plant-densities. Usage of the lower level of fertilizer application resulted in a greater annual diameter-increase; the results were not constant with the production of chupons.

The treatments with the looser plant densities had smaller number of 'pod lost' per unit area, due to infections by Phytophthora. Greater amounts of pods were lost due to infection by Phytophthora when the higher level of fertilizer application was employed.

Strong, positive correlations between tree-girth and yield, as well as between the number of usable pods harvested and yield of cocoa, were observed.

Up to now, it can be concluded that it is best to plant cacao at 2 x 3 m and not thin-out them at the other plant-densities and distributions tested. Also, the lower level of fertilizer application is better in terms of yield-response, under the existent experimental conditions.

## INTRODUCTION

Several cocoa producing countries are faced not only with an ever decreasing area of land under cocoa production, but also with a smaller amount of harvest or produce per unit of land. The net effect of these factors is often a marked reduction of the quantity of dried beans which such countries can produce for export and/or [illegible] consumption. Since the early 1950's there has been a move to closer spacing, a more drastic reduction in shade levels and greater use of fertilizers.

Several researchers have demonstrated the positive effects of fertilizer use on cocoa yields (3, 4). On the other hand there is evidence that some elements actually depress yield depending on the [illegible] in the cocoa plantation (2, 1, 12). [illegible] of diseases have also been reported (11, 3) in cocoa, due to fertilizer usage. Thus, one should be mindful of these implications in the evaluation of the fertilizer requirements of cocoa.

Results from many experiments indicate high cocoa yields, at least during the early years of establishment are superior when planted at closer spacings (3, 6).

Urquhart (10), suggests that the best way of obtaining high yields over long periods, is to plant at closer distances and thin-out the plantation as the trees grow. Because competition in cocoa after about eight years of age reduces it to an undesired level in terms of nutrients, water and [illegible], thinning out process would seem to be necessary to maintain the real economically surpass, initial yields. Due to the need to [illegible] the amount of shade,

to thin out after competition arrives at an undesired level, and to optimize the use of fertilizers, research which would examine the effects of these, as well as their interactions, is imperative.

The following work seeks to:

1. Evaluate different densities of plantation and pattern of distribution of cacao plants of two years of age. This evaluation will be of agronomic characteristics.
2. Evaluate the reaction of the said cacao plants to fertilizer treatments.

## MATERIALS AND METHODS

### Locality

This experiment was carried out at the farm "La Lola, situated on an alluvial flat which forms part of the atlantic coastal plain of Costa Rica. The height above sea level is 40 m, the mean temperature is 25°C and the mean annual rainfall is 3652 mm (mean from 1949 - 1977). Although the rainfall is more or less continuous year-round, there are two periods in the year (February - April and August - September) in which there is less rainfall.

### Experimental area and materials used

The trial was established in sections 6 and 8 of "La Lola", these sections are populated by four hybrids, planted at 2 m x 2 m and 2 m x 3 m respectively in 1968. The fertilizer treatments were carried out in three applications during the period of time of this trial (one year), in June, September and December, 1978. These were done as they usually are in "La Lola", in a band of radius 40 cm around the tree-trunk.

All the plots received two fungicidal applications. The fungicide (Kocide-101) was applied at a dosage of 50 g/3.7 liters water with 2 ml. Triton (sticker-spreader) and 10 g EDC (insecticide)

The hybrids had their origin from biclonal crosses between UF-613 x Catongo, IMC-67 x UF-676, UF-29 x Catongo, and UF-677 x Pound - 7. The shade was supplied by Erithrina spp. which was more or less uniform in height and distribution.

The state of the trees were assessed in each section, a year before this work commenced, according to the categories described by Mariano (5).

In addition to these classifications, the criterion of trunk-diameter was used to avoid subjectivity. A tree was considered as being weak if the diameter was less than the average in addition to belonging to category one (5).

The treatments applied (one year before this experiment begun) were the following:

| | | | | |
|---|---|---|---|---|
| 1. | Present arrangement (control) | (T1) | 1667-2500 tree/ha | |
| 2. | Triangular arrangement | (T2) | 833-1250 tree/ha | |
| 3. | Removing 50 per cent of the weak trees | (T3) | 1400-2031 tree/ha | (Section 6) |
| | | | 900-1510 tree/ha | (Section 8) |
| 4. | Elimination of every other row | (T4) | 833-1250 tree/ha | |
| 5. | Removing 100 per cent of the weak trees | (T5) | 1250-1494 tree/ha | (Section 6) |
| | | | 1011-1392 tree/ha | (Section 8) |

Superimposed on these treatments were two levels of fertilizer application. The higher level of fertilizer application was 2250 kg/ha of the complete fertilizer mixture, 10:10:6; the other level being 1,500 kg/ha of the same fertilizer.

These treatments were arranged in a completely randomized split-plot design, with four repetitions in each one of the two sections.

Data collection

Measurements were made of trunk-diameter at 30 cm from the soil and the height of the jorquette at the commencement of the trial (15 March, 1978), six months later, nine months later and also at the end of the trial (15 March, 1979).

During the experiment, the number and fresh weight were taken of the chupons removed, for each tree. Also, the number of fruits and the fresh weight of the beans per tree, and per plot and sub-plot, were taken. The chupons were evaluated every three months and the cocoa yield data were taken every 15 days, weighing the beans at the time of harvest.

Measurements of trunk-diameter were taken with a wooden guage graduated in millimeters taking care that the measurements were always taken in the same orientation, being North-South. The height of the jorquette was measured with a wooden rule graduated in centimeters.

With the aim of measuring other effects of the treatments, the number of fruits affected by Phytophthora palmivora, but whose seeds were still usable, as well as the number of discarded fruits due to this pathogen, was evaluated at the time of harvesting.

## RESULTS AND DISCUSSION

### Yield responses.

Table 1 indicates the yield/ha, yield/plant, number of pods discarded due to infection by Phytophthora palmivora and the number of usable pods harvested in both Sections 6 and 8.

Section 6 (2 x 2 m)

T3 (50% of the weak trees eliminated) had the greatest yield/ha, followed by T1 (control treatment); the least yield response was with T4 (every other raw eliminated). Thinning treatments with plant densities and distributions of T2 (every other tree eliminated) and T4 had an over-abundance of light, and, coupled with broken canopy-systems, permitted a luxurious growth of weeds. The end

Table 1: Yield/ha, Yield/Plant, the number of pods discarded or lost due to Black Pod disease and the number of usable pods harvested in both Sections 6 and 8

| Treatment | Yield/ha | | Yield/Plant | | Discarded/Pods | | Usable Pods/harvested | |
|---|---|---|---|---|---|---|---|---|
| | Section 6 (2 x 2 m) | Section 8 (2 x 3 m) | Section 6 | Section 8 | Section 6 | Section 8 | Section 6 | Section 8 |
| $T_1$ $F_1$ | 1650.03 | 2862.50[a] | 0.83 | 2.29 | 0.62 | 2.38 | 7.24 | 19.13[ab] |
| $T_1$ | 2001.25 | 2487.44 | 0.94 | 1.34 | 0.60 | 1.56 | 7.32 | 16.40 |
| $F_2$ | 2374.13 | 1990.40[b] | 1.03 | 1.39 | 0.50 | 1.54 | 7.39 | 9.66[b] |
| $T_2$ $F_1$ | 2156.40 | 1653.45[b] | 1.84 | 2.19 | 0.73 | 1.35 | 10.54 | 17.34[ab] |
| $T_2$ | 1758.03 | 1942.00 | 1.56 | 2.07 | 0.75 | 2.07 | 9.12 | 23.13 |
| $F_2$ | 1150.[illegible] | 2120.46[ab] | 1.28 | 3.54 | 0.78 | 2.78 | 7.70 | 28.20[a] |
| $T_3$ $F_1$ | 2566.[illegible]3 | 2675.00[ab] | 1.45 | 2.14 | 1.14 | 0.91 | 10.79 | 14.90[ab] |
| $T_3$ | 2335.1 | 2226.60 | 1.50 | 1.80 | 1.13 | 1.23 | 9.50 | 12.71 |
| $F_2$ | 2074.00 | 1774.00[b] | 1.13 | 1.45 | 1.13 | 1.55 | 8.22 | 10.53[b] |
| $T_4$ $F_1$ | 1914.77 | 1510.00[b] | 1.[illegible]9 | 2.00 | 0.85 | 1.60 | 11.26 | 15.45[ab] |
| $T_4$ | 1647.24 | 1525.10 | 1.68 | 2.02 | 1.03 | 1.71 | 10.54 | 14.37 |
| $F_2$ | 1378.44 | 1540.20[b] | 1.26 | 2.04 | 1.22 | 1.82 | 9.81 | 14.51[ab] |
| $T_5$ $F_1$ | 2050.50 | 2500.00[ab] | 1.53 | 2.40 | 0.50 | 1.71 | 9.51 | 18.53[ab] |
| $T_5$ | 1831.78 | 2472.32 | 1.34 | 2.11 | 0.8 | 1.63 | 8.66 | 15.13 |
| $F_2$ | 1599.39 | 2[illegible]2.66[ab] | 1.17 | 1.83 | 1.11 | 1.66 | 7.[illegible]0 | 13.43[ab] |
| $F_1$ (average taken across the five thinning Treatments T1 to T5) | 2069.73 | 2240.35 | 1.47 | 2.21 | 0.77 | 1.59 | 9.87 | 17.15 |
| $F_2$ (Average taken across the thinning Treatments - T1 to T5) | 1779.38 | 1961.72 | 1.17 | 2.05 | 0.96 | 1.87 | 8.14 | 15.37 |

*The means with the same letter do not differ from each other statistically.

F1 = low level of fertilizer application (1,500 kg/ha) F2 = High level of fertilizer application (2,250 kg/ha)

result was lower yield/ha in these treatments. On the other hand too much competition was present in T1 for it to out yield T3.

The thinning-out of 50% of the weak trees permitted the strong trees to yield much more, as well as the 50% of the weak trees which were left. The contribution to yield of the 50% weak trees left was more than the added increase in production of the strong trees when 100% of the weak trees were eliminated. Thus, T3 outyielded T5 also. This is in agreement with Peralta (7) who worked on the same problem in the same area.

T4 produced the greatest number of pods/plant while T1 had the least. This tendency was repeated with the number of pods made non-utilizable due to infection by *Phytophthora*. It seems that the more pods present in a plantation the greater the probability that more pods will be infected by *Phytophthora* as well as made non-utilizable as a result of the infection. Actually a high degree of correlation between the number of pods and the number of pods made non-utilizable due to the infection was found. A high positive correlation was also found between the yield of wet cocoa and the number of usable pods harvested.

Due to decreased competition for root-room, nutrients and at times water, the plants performed better individually in the treatments T2 and T4.

The lower level of fertilizer application provoked a greater yield response in both yield/ha and yield/plant. The probable reason could be due to the great nutrient imbalance (k/mg) found in the soil. Also, it should be noted that the recommended fertilizer dosage at the experimental site is the lower level (1,500 kg/ha 18:10:6).

The above conclusions can be drawn although statistical significance between treatment means were not found.

Section 8 (2 x 3 m).

Once again T2 and T4 were the treatments most prone to insect infestation and damaging weed growth because of their plant-densities and distributions. T2 had greater yield responses than T4 because of its better plant-distribution, avoiding more weed growth. T5 produced the greatest yield/ha, followed by T1 (control). The difference in yield/ha is only 5 kg/ha.

When the number of pods discarded due to Phytophthora infections is taken into account, the potential yield/ha of T1 is much greater than T5. Thus, it seems that the original planting distance is still adequate in terms of non-competition for nutrients and root-room. This is in agreement with Peralta (7). It should be noted that T1 of section 8 out-yielded T5 of section 6 by about 6%, both being the best treatments in their respective sections.

Generally the treatments (T2 and T4) with lesser plant densities had better yield responses than the others on an individual tree basis (Table 1). The possible reasons cited for Section 6 holds true here also.

In a less marked fashion than Section 6, it can be seen that the greater the number of pods harvested per tree, the greater the number of pods that are made non-utilizable due to infection by Phytophthora.

Analyses of variance carried out on the data gave statistical significance among the treatment means at the 5% level for yield/ha,

as well as number of pods harvested/plant. No statistical differences among treatment means were found with the other variables.

Sections 6 and 8.

From yield data during eight years, Section 6 has generally outyielded Section 8 during the early years of production. After 1976 (or about eight years after planting), Section 8 began outyielding Section 6. It will be useful for this experiment to be continued to see at what age Section 8 will permanently outyield Section 6.

Vegetative responses

Statistical differences among treatment means were not found in neither of the two sections. Table 2 shows the vegetative responses obtained.

Section 6

The treatment means indicate that the treatments with lesser plant densities had greater diameter-increases, T2 and T4 having values of 7.815 mm and 7.520 mm, respectively. On the other hand the indication is that the treatments with lesser plant densities (T4) had the least jorquette-height-increases.

This is understandable, treatments with greater root-room and air-space, tend to have less competition for nutrients. Thus, individually these plants perform better, not only in yield but also in diameter-increases. High plant densities obviously induce the competitive forces which provoke an "upward rush" for light, principally. This is borne out by the response of

Table 21: Annual diameter and jarquette-height increases, as well as the fresh-weight and number of chupons produced in both Sections 6 and 8.

| Treatment | | Annual Diameter Increase | | Annual Jarquette-height Increase | | Chupon weight | | Chupon # | |
|---|---|---|---|---|---|---|---|---|---|
| | | Section 6 (2 x 2 m) | Section 8 (2 x 3 m) | Section 6 (2 x 2 m) | Section 8 (2 x 3 m) | Section 6 (2 x 2 m) | Section 8 (2 x 3 m) | Section 6 (2 x 2 m) | Section 8 (2 x 3 m) |
| $T_1$ | $P_1$ | 9.617 | 6.460 | 9.822 | 11.163 | 0.618 | 1.264 | 15.730 | 21.298 |
| | | 6.781 | 5.905 | 9.411 | 9.536 | 0.589 | 1.080 | 14.624 | 19.153 |
| | $P_2$ | 3.946 | 5.350 | 8.999 | 7.908 | 0.560 | 0.895 | 13.518 | 17.009 |
| $T_2$ | $P_1$ | 8.271 | 6.040 | 15.853 | 7.629 | 0.895 | 1.578 | 18.031 | 24.420 |
| | | 7.815 | 7.112 | 11.803 | 7.196 | 1.016 | 1.445 | 20.164 | 25.177 |
| | $P_2$ | 7.360 | 8.185 | 7.772 | 6.762 | 1.140 | 1.312 | 22.298 | 25.935 |
| $T_3$ | $P_1$ | 5.000 | 6.723 | 11.453 | 5.298 | 0.754 | 1.103 | 19.320 | 21.403 |
| | | 5.197 | 5.976 | 12.423 | 5.836 | 0.776 | 1.056 | 17.213 | 20.159 |
| | $P_2$ | 5.394 | 5.230 | 13.390 | 6.473 | 0.798 | 1.010 | 15.106 | 18.914 |
| $T_4$ | $P_1$ | 7.229 | 9.656 | 3.831 | 6.662 | 1.004 | 1.089 | 20.153 | 15.525 |
| | | 7.520 | 9.025 | 4.942 | 6.365 | 0.925 | 1.210 | 18.702 | 13.147 |
| | $P_2$ | 7.813 | 8.394 | 6.053 | 7.069 | 0.847 | 1.331 | 17.250 | 22.769 |
| $T_5$ | $P_1$ | 5.600 | 8.035 | 10.095 | 8.443 | 0.705 | 0.500 | 25.100 | 15.588 |
| | | 5.568 | 8.005 | 12.459 | 8.333 | 0.775 | 0.958 | 20.443 | 16.036 |
| | $P_2$ | 5.443 | 7.957 | 14.914 | 8.223 | 0.756 | 1.016 | 17.705 | 18.484 |
| $P_1$ (average taken across the five thinning Treatments- $T_1$ to $T_5$. | | 7.379 | 7.334 | 10.350 | 7.839 | 0.811 | 1.187 | 19.283 | 19.267 |
| $P_2$ (average taken across the five thinning Treatments- $T_1$ to $T_5$. | | 6.173 | 7.023 | 10.067 | 7.687 | 0.822 | 1.113 | 17.176 | 20.622 |

$P_1$ = low level of fertilizer application (1,500 kg/ha) $P_2$ = high level of fertilizer application (2,250 kg/ha)

T4; having the least jorquette-height-increase. The response of T2 is a bit confusing.

The use of the lower level of fertilizer caused greater responses in both diameter and jorquette-height-increases.

With the weight of chupons produced, the treatments with greater light intensities (T2 and T4) had the highest values. The ample air-space and greater light intensities induced these treatments to produce greater weights of chupons; the higher level of fertilizer use resulted in the greater production of chupons.

Section 8

Essentially the same trends as in Section 6 were observed (Table 2), and the reasons cited earlier also apply here. The only marked difference is with the production of chupons using the different levels of fertilizer. In this case the use of the lower level provoked a greater production of chupon (fresh-weight); the results seem to be unclear in this aspect.

Sections 6 and 8

In section six, the average trunk-diameter increase per treatment per year was 6.83 mm in section 6 while in section 8, the value was 7.21 mm. These figures are much higher than those reported by Alvim cited by Peralta (7)), who stated that the average annual increase in trunk-diameter was 3.81 mm. Differing also from the results of this experiment, are the corresponding figures for sections 6 and 8 (being 3.45 mm/year and 3.41 mm/year, respectively) given by Peralta (7).

However, all the diameter-increase figures given are considerably less than those obtained in Nigeria by Are and co-workers (Are, L. A. and Ogunkva, I. O. cited by Peralta (7)). They report that in a plot of cacao planted at 1.5 x 1.5 m and, thinned at six years old to different distances and distributions of the trees, a diameter-increase of 16 mm per year in the case of the lower plant-densities.

Correlations -

High positive correlations were found between yield and trunk-diameter measured at 0.3 m above the surface of the soil, as well as with the number of pods harvested. This was true for the both Sections. Other researchers have found results of this nature (5).

## CONCLUSIONS AND RECOMMENDATIONS

(1) The trunk-diameter measured at 0.3 m above the soil surface can be used as a calibrating variate for yield. Use can be made of this in thinning practices.

(2) It is better to plant cacao at 2 x 3 m and not thin-out than to plant cacao at 2 x 2 m and then thin-out after eight years.

(3) The use of the lower level of fertilizer (1,500 kg/ha 18:10:6) is better than the higher level (2,250 kg/ha) as regards yield response and incidence of Black Pod disease. This applies to the soil and climatic conditions that existed at the experimental site.

(4) The treatments with lesser plant densities (T2 and T4) performed better and had smaller numbers of pod loss due to Phytophthora infection, on an individual plant basis.

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