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Influence of three pruning intensities on productive characteristics of cocoa (Theobroma cacao L.) CCN-51 clone

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***Abstract*---**The cultivation of cocoa (Theobroma cacao L.) is a widespread crop and occupies an increasing number of hectares of agricultural land distributed throughout almost all of Ecuador. The agronomic management of this crop consists of different agricultural tasks of which pruning is one of the main ones. In many cocoa farms, pruning is done incorrectly, causing the cocoa trees not to reach their ideal structure and leading to low production. Cocoa is of great importance as a source of external income for the country. The objective of this research is to evaluate three pruning intensities in CCN-51 cocoa and their influence on production. Three treatments with different pruning intensities of 25%, 50%, and 75% (T1, T2, and T3, respectively) were studied. Each treatment consisted of 10 plants and 4 replicates, for a total of 120 plants. A RDBC randomized complete block design was used. Health and production data were evaluated for each plot. For the healthy fruit variable, T1 pruning at 25% obtained the best result, while for diseased fruit, T2 pruning at 50% obtained a good result. The best values for fresh fruit weight and nut yield were obtained for the T1 treatment as 123.50 kg/ha and 30.49 qq/ha, respectively. In conclusion, pruning at 25% is an alternative to increase cocoa productivity, as it requires little expense and is a good practice to carry out.

***Keywords*---**agronomic practice, yield, productive characteristics.

Introduction

Cocoa (*Theobroma cacao* L.) is a tropical fruit whose production is concentrated mainly in the provinces of Los Ríos, Guayas, Manabí and Sucumbíos of Ecuador. Two types of cocoa are grown in the country including Cocoa CCN-51 and the so-called National Cocoa (Pilaloa *et al.*, 2021). To Rojas-Molina *et al.*, 2021), cocoa has been consolidated worldwide as a production system of great commercial importance as it is a raw material in the food, cosmetic and pharmaceutical industries. In addition, its compatibility with sustainable development is recognized due to its nature as a perennial species and production under agroforestry systems. According to (INEC, 2021). In Latin America, Ecuador is the main cocoa producer with a cultivated area of 590,579 ha and an almond yield of 0.62 t/ha (Vera *et al.*, 2021). On the other hand, Ecuador is considered one of the main cocoa exporters in South America and the first producer of high-quality "fine" grade cocoa beans in the world.

There is a diverse genetic variability adapted to the different climatic parameters found in the agro-ecological zones of the country, which allows its cultivation under the conditions of different production systems and in association with species such as cassava (*Manihot esculenta* Crantz.), plantain (*Musa* sp.), as transitional shade or with permanent shade systems with fruit or timber trees, which allow farmers to have additional sources of income (Antoninez *et al.*, 2020). Likewise, low yields are also determined by the low adoption of available technologies. In addition, the type of clone that is being used must be taken into account, given that there are agro-environmental factors, cultivation, and harvesting techniques in the region, and the type of cocoa tree affects the quality and productivity (Montealegre *et al.*, 2021).

Cocoa farms and regions are in a state of neglect due to the lack of support to cocoa farmers to grant them credit and incorporate new technologies into agriculture. In addition, most of the plantations are old, ranging from 30 to 40 years (De la Cruz-Landero *et al.*, 2015). One of the common management practices applied to cocoa is pruning, which modifies leaf area and affects vegetative, reproductive, and production variables (Leiva-Rojas *et al.*, 2019).

These authors also indicated that there is uncertainty about when and how to prune to ensure the greatest benefit to farmers. In cocoa, pruning is necessary because it influences the increase in yield and good tree architecture, consists of removing diseased, poorly formed, and undesirable branches that compete for nutrients with productive branches and allow better absorption of nutrients from the soil, good aeration and the entry of light that contributes to the formation of an unfavorable microclimate for pests and diseases (INIAP, 2014). One of the advantages of pruning is also to stimulate the development of new buds and renew the photosynthetic apparatus of the plant, with the expectation of balancing vegetative growth with reproductive growth, thus ensuring greater productivity and grain quality (Gutiérrez-Brito *et al.*, 2019).

Pruning in cocoa cultivation is classified into training, maintenance, production, sanitation, and rehabilitation. Depending on the type, residues of different plant materials associated with parts of the plant such as leaves and twigs, and

secondary or primary branches are produced (Echeverri-Rodriguez, 2013). The objective of this study was to evaluate 3 pruning intensities on cocoa clone CCN-51 and their effects on yield.

Materials and Methods

Location of the study

The present research was carried out on the campus of La Cadena, belonging to the canton of Valencia, province of Los Ríos. Its geographical location is 1° 03´ 18" south latitude and 79° 25´ 24" west longitude at an altitude of 90 meters above sea level. The approximate age of the trees was 6 years. During the winter, data were taken every 15 days for 3 months. The data recorded corresponds to a cycle.

Management and evaluation design

The objective of the present research was to know the response of clone CCN-51 to pruning at different intensity levels. Therefore, pruning was the only factor under study, which was implemented through three increasing pruning intensities that were transformed into the respective treatments including 1) T1, light pruning which was the elimination of 25% of the crown by cutting branches, twigs, and foliage, 2) T2, intermediate pruning which consisted of the elimination of 50% of the crown and 3) T3, drastic pruning which was the elimination of 75% of the crown. The morphoagronomic variables evaluated in this study were the number of healthy fruit which was evaluated at harvest every 21 days, the number of diseased fruit which was evaluated along with the previous variable while counting all diseased fruit, and the fresh weight yield per treatment (kg/ha). The yield was recorded individually per treatment for the trees in each plot, but then these records were summed to obtain an average fresh fruit weight for each treatment. Finally, the last variable was nut yield per treatment (qq/ha). The weight was obtained from the mean of seven dry almond yields from 10 surveyed plants that were randomly chosen in the treatment area, then multiplied by the 1111 pl/ha and divided by 1000.

Diseño experimental y análisis estadístico

A randomized complete block experimental design was used, with three treatments (pruning intensities at 25%, 50%, and 75%). There were four replicates per treatment. Each treatment consisted of 10 plants, giving a total of 120 trees in the experimental plot. Analysis of variance and comparison of means was performed using Tukey's test ($p < 0.05$). The InfoStat program (Di Rienzo *et al.*, 2018) was used for the statistical analyses.

Results and Discussion

The low productivity of traditional cocoa orchards is the main cause of low producer income. Pruning is a necessary practice for the formation, health, and maintenance of the functionality of the cocoa plant and the orchard as a whole. In Figure 1, the number of healthy fruits in the different pruning intensity treatments showed a significant statistical difference. The highest mean value of

this variable was presented by T1 with 203.75 healthy fruits and was statistically similar to the results of T2 with 179.75 healthy fruits. These values were different from those of T3, with 170.00 healthy fruits. The coefficient of variation for this variable was 9.11%.

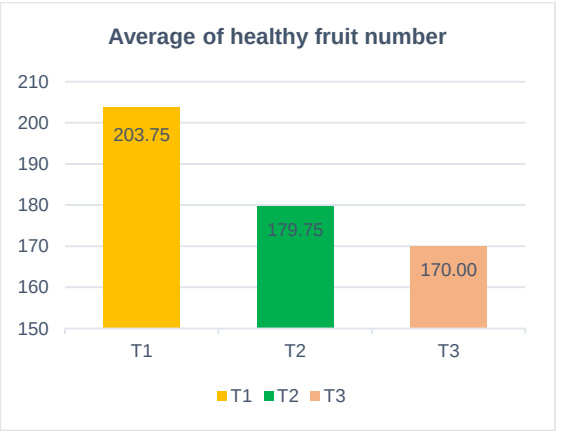

Figure 1. Averages of the number of healthy fruits from different pruning intensities on CCN-51 cocoa. Healthy fruits were dependent on pruning intensity and showed a decreasing pattern from light to drastic pruning intensity

The present values exceed the results recorded by (Leiva-Rojas *et al.*, 2019), where the vegetative and reproductive behavior of cocoa by pruning effect was investigated and in cocoa CCN- 51, the highest number of harvested fruits was obtained for the treatment (-b25%) with 57 healthy fruits/tree. On the other hand, in the research work conducted by (Vera *et al.*, 2021), in the number of healthy fruit spikes, a high significance was obtained in T21 (drastic pruning, seed CCN-51) with 10.00 healthy fruit spikes. Results from other reports showed that cocoa plants were positively affected by the type of pruning and even when excessive pruning was performed but under conditions of good soil fertility (Hartemink (2005), Puentes Paramo et al. (2014); Rivera-Fernandez *et al.* (2014); and Lopez *et al.* (2016). One of the immediate effects observed in the application of pruning is that, as shading is reduced, there is a greater entry of light and better ventilation of the plantation, the effects of which are notable since the induction of buds that give rise to fruit spikes both at the base and at the top of the trunk is stimulated. In addition, the average number of fruit spikes induced per plant both in the aerial part and at the base of the pruned trunks is higher than that of the control treatment trees (Sánchez-Gutiérrez, 2020).

As for diseased fruit (moniliasis and black spike), mean values of the number of diseased fruit were appreciated (Figure 2). The analysis of variance determined that there was no statistical significance among the treatments evaluated. The coefficient of variation was 30.26%. The highest number of diseased fruits was observed in T1, with an average of 46.75 fruits per plant. T2 and T3 showed similarities in the averages, but T2 had fewer diseased fruits with an average of 32 diseased fruits per plant.

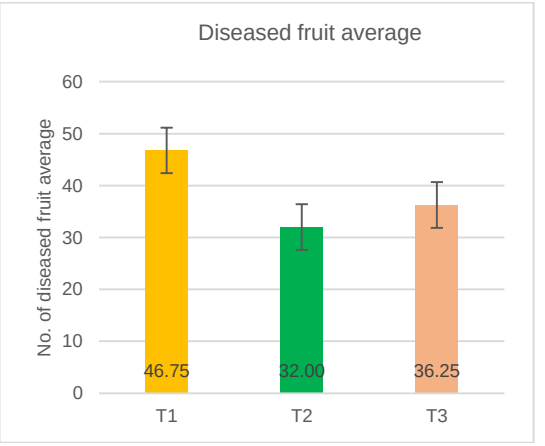

Figure 2. Average number of diseased fruits in 3 pruning treatments for CCN-51 cocoa. Pruning at 25% showed more diseased fruit than the other two intensities

In a research report, the authors indicated that the type of pruning had a significant effect on the number of diseased fruit. They also indicated that the location of the tree in the lot significantly affects (Trujillo, 2019). When a plantation is very tall, old, or in an abandoned condition, pruning allows more light to enter, greater air circulation, and increases the production of larger terminal buds, which translates into an increase in fruit production per tree (Valdés, 1988; López *et al.*, 2016).

As shown in Figure 3, for the variables of fresh fruit weight (kg/ha) and dry fruit yield (qq/ha), the treatments with pruning intensities presented significant statistical differences. The coefficient of variation for these two variables was 9.60%, respectively. Treatment T1 showed a significant statistical difference with 123, 50 kg/ha, compared to treatments T2 and T3. The latter two showed similar values to each other. About nut yield (qq/ha), the highest yield was recorded in T1 with 30.49 qq/ha and the lowest value, with 21.11 qq/ha, corresponded to T3. A yield of 24.47 qq/ha was observed in the T2 treatment.

These results are in line with the results reported by Leiva-Rojas *et al.* (2019), who obtained the highest yields for trees with lower pruning intensity. According to (Lopez et al., 2016), canopy pruning of shaded cocoa increased yield. Based on our results, the effects of different types of pruning on yield are evident, as they are also consistent with what was reported by Moreira (1992), who mentioned that maintenance pruning should be light, i.e., not cutting many branches with leaves to ensure a good leaf area. Up to 30% of the leaf area can be eliminated (Arnawa et al., 2019).

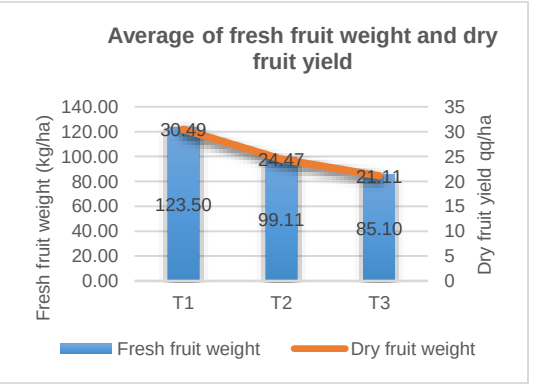

Figure 3. Averages of fresh and dried fruit weight were obtained for the 3 treatments. Values for fresh fruit weight are shown in bars, while those for dry fruit weight are in line. From T1 to T3 the values decreased, suggesting that light pruning was more effective than higher pruning intensities

Conclusion

The application of different pruning intensities generated favorable effects for the CCN-51 cocoa crop to a large extent. These effects were manifested with an increase in yield averages. Pruning is an activity that is carried out in the cocoa crop and its proper management can generate benefits in both production and phytosanitary control, in addition to obtaining a better distribution of nutrients and aeration of the plantation.

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