

Methods of pruning and thinning in a flooded camu-camu plot

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ABSTRACT

A 20-year-old camu-camu plot was studied to determine pruning production and stand-thinning techniques with the objective of recovering its productive capacity in a floodable area. The evaluated treatments were as follows: T1 “control” (without pruning and without stand-thinning), T2 (without pruning and with stand-thinning per line), T3 (with pruning and stand-thinning per line), and T4 (with pruning and selective stand-thinning). The distribution of plants in the field was not balanced, and the INFOSTAT program was applied for the non-parametric analysis of Kruskal and Wallis with 8 replicates. The response variables were as follows: “Number of flowers/plant” (NFL), “number of fruits in phase 3” (NFRF3), “number of fruits in phase 5” (NFRF5), “percentage of fallen fruits in phase 3” (% FRCF3), “percentage of fallen fruits in phase 5” (% FRCF5), “average fruit weight” (PPFR), and “fruit yield” (RFR). Significant differences were found between treatments for NFL, NFRF3, NFRF5, % FRCF3, and RFR with values: $P = 0.0002$, $P = 0.0022$, $P = 0.0009$, $P = 0.0010$, and $P = 0.0010$, respectively. The percentage of fruits fallen in % FRCF5 and PPFR were not statistically influenced by the treatments. T2 reached higher values in all these variables. In the 10 months of the trial, T2 induced a significantly higher RFR, evidencing the disadvantage of pruning and the efficiency of linear thinning in the short term. It is necessary to continue evaluating the next harvests to observe the RFR trends.

1. INTRODUCTION

The experience of research and promotion of camu-camu (*Myrciaria dubia*) in Peru began the several decades ago with the nutritional analysis of its fruit, whose surprising result was 2780 mg/100 g of ascorbic acid [1]. This finding aroused interest in its use and research and continued botanical, agronomic, and industrial studies. The camu-camu inhabits in natural conditions in the floodable banks of a great quantity of rivers of South America. In Peru, natural camu-camu populations have been identified in the Nanay, Itaya, Napo, Putumayo, Yavari, Marañón, and Ucayali rivers [2]. According to Yuyama *et al.* [3], camu-camu is a natural species in the lowlands of most of the rivers, lakes, and floodplains of the Amazon basin.

The camu-camu is a bush of 4 to 6 m of height, the fruit is globose, from 1 to 3.2 cm in diameter, dark red color when the maturity is complete (Picón and Acosta, 2000) [4]. According to Pinedo

et al. [1], the fruits have a diameter of 2.4-2.6 and weigh an average of 6.9 g.

In most of the camu-camu plantations established in 1997, when agronomic management technologies were not available, 3 m × 3 m distances were applied. Under such a design, if proper management is not done, after 9 years of planting, competition between plants is accentuated and becomes critical, which makes it necessary to prune or reduce the population (stand-thinning) of the plants [5-7]. Imán and Melchor [8] proposed that, when sowing at distances of 2 m × 2 m (2500 plants/ha), it will be necessary to eliminate a row of plants at 6 years and thus achieve a distance of 4 m × 2 m with a density of 1250 plants/ha. According to Vásquez [9], pruning in the cultivation of camu-camu is as important as in any other fruit, after of more than 10 years, and taking into account, the conditions of the plants could to be recommendable the renovation-prune leaving two or three stems per plant. The production prune consists of cutting off the branches that were last harvested and is practised to favor the development of the branches close to produce fruits, which have diameters of 6-14 mm [1]. With this pruning, it is intended to maintain the entrance of light all the time, the constancy of the fruiting, and the quality of the fruits [10]. This particular pruning is of great importance in orchards that are in full productive life, and it is focused on controlling the size of the trees, keeping that with the tops separated and vigorous,

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preventing their aging, since by that frequent prunings, the foliage is renewed continuously [11].

Shiva and Tanka [12] found that the number of fruits per outbreak and yield decreased significantly with a higher level of pruning in guava (*Psidium guajava*). However, Abanto *et al.* [13] obtained better fruiting in plants that were pruned, obtaining 8462 floral buds/plant and 5805 fruits curdled/pl. In addition, by manual defoliation with pruning, it obtained the highest yield of fruit with 19.65 t/ha.

The objective of this research is to determine the pruning and elimination of excess plant (stand-thinning) technologies to recover productive capacity in advanced plantations of camu-camu.

2. MATERIALS AND METHODS

2.1. Location of the Experimental Field

The present research was carried out in the community of Santa Rosa, Amazon River, district of Belen, between coordinates 03°42'24.0" South Latitude and 73°11'01.5" West Longitude. The area is located within a complex of banks of the Amazon river (Figure 1) characterized by dykes and physiographic depressions vernacularly known as "restinga" and "bajiales." The banks are subject to a process of lateral erosion and are formed from the sediments carried by river waters during the flood.

The annual average temperature of the area was 27.45°C, relative annual humidity of 86%, and annual precipitation of 3111.4 mm [14].

2.2. Treatments in Study

For the study, they were selected two hundred plants of 20 years of age, spaced at 3 m × 2 m occupying an area of 1200 m². The plants were pruned at 3 m height at 15 years of age, and the current height of the plants is 4.5 m.

The 4 treatments had 8 replications, where the experimental unit was an adult plant.

The treatments were as follows:

T1(control): Without pruning and without stand-thinning; T2: Without pruning and with stand-thinning per line, a row of plants was eliminated, leaving a distance of 6 m × 2 m; T3: With pruning and stand-thinning per line, a row was removed and pruned fruiting with a cut of 15 cm and T4: With pruning and with selective stand-thinning, it consisted in eliminating plants with undesired architecture, and the remaining were pruned as in T3.

2.3. Variables Evaluated

The evaluation of the variables related to flowering and fructification took into account the information about the reproductive phenological cycle the same that occurs in 77 days and is divided into two states: Flower development, involving four phases, and development of the fruit that includes eight phases [15]. The flowering phases are as follows: (1) From the appearance of the floral bud and the subsequent 7 days. (2) The floral bud experiences a growth in its length and diameter until presenting a form similar to that of a balloon. This phase comprises 7 days. (3) The floral button opens and the style first emerges. Then, in the morning, the stamens emerge. At this moment, the flower is pollinated, and the presence of bees (*Melipona fuscopilara* and *Trigona itatica*) is observed. (4) Once the style emerges and is pollinated, the stamens of the flower begin to come off. Phases 3 and 4 comprise between 4 and 5 h.

From the appearance of the floral bud to the beginning of the fruit formation, 15 days pass.

Fruiting phases are as follows: (1) Once the flower is fertilized, the stamens and sepals are released. The style takes the form of a light green brad that measures 0.15 cm in height. This phase comprises 7 days. (2) The fruit that had the shape of a brad continues its development and adopts a dark-green coloration. It can measure between 0.16 and 0.35 cm in length. This phase also comprises 7 days. (3) It is observed that the fruit increases its size. Its coloration remains green and can measure between 0.36 and 0.60 cm. This phase comprises 12 days. (4) The fruit maintains its green color and measures between 0.61 and 1.0 cm in diameter. From this phase, which lasts for 10 days, the fruits are considered physiologically developed. (5) In this phase, whose duration is of 7 days, the fruit reaches to measure 2.4 cm of diameter and to have an average weight of 7.5 g. (6) The fruit has small reddish spots. Therefore, it is called "pintón verde." It also measures 2.5 cm in diameter and its weight is 9.3 g on average. This phase comprises 7 days. (7) The fruit has a reddish-green color: Light red with green spots. It is called "mature-pint." It measures 2.6 cm in diameter and weighs 10.3 g on average. This phase comprises 6 days. (8) The fruit, in its entirety, is red wine. It is considered a mature fruit. It measures 2.5 cm in diameter and weighs 10 g on average. This phase comprises 6 days.

The following characters were evaluated:

Number of flowers (NFL) defined as the total NFL counted in the four phases of flowering.

Number of fruits in phase 3 of fruiting (NFRF3) defined as the total number of fruits between 19 and 26 days after the beginning of fruiting (Inga *et al.*, 2001).

Number of fruits in phase 5 of fruiting (NFRF5) defined as the total number of green fruits counted between 36 and 43 days after the beginning of fruiting (Inga *et al.*, 2001).

Percentage of fallen fruits to phase 3 (% FRCF3). This variable was calculated by dividing the number of fruits that reached phase 3 on the NFL and multiplying the resulting quotient by 100.

Percentage of fruits fallen to phase 5 (% FRCF5). This variable was calculated by dividing the number of fruits that reached up to phase 5 between the number of fruits of phase 3 and multiplying the resulting quotient by 100.

Average fruit weight (PPFR), resulting from the individual weight of 20 fruits in green and Pinton states (phases 5 and 6) taken at random, expressed in grams.

Fruit yield (RFR), product of the multiplication of NFRF5 by PPFR, the result was expressed in grams/plant.

2.4. Statistical Methods

The InfoStat program (Version 2011e) [16] was used, but previously data were evaluated by normality tests (using graphs) and homogeneity of variances (with scatter diagrams). For the analysis of variance and according to the nature of the variables, the non-parametric Kruskal-Wallis test was applied for the seven variables under the study. This test is based on the calculation of the sum of R_m ranges for each group m=1 ... r, where:

r = Number of groups,

R_m = Sum of ranges of each group m.

The mean value of the ranges $E[R_m]$ is calculated as follows:

$$E[R_m] = \frac{n_m(n+1)}{2}$$

And, the average range R_m is as follows:

$$\bar{R}_m = \frac{R_m}{n_m}$$

Then, the Kruskal-Wallis H contrast statistic is calculated as:

$$H = \frac{\frac{12}{n(n+1)} \sum_{m=1}^r \frac{1}{n_m} [R_m - E[R_m]]^2}{1 - \frac{\sum_{j=1}^k (d_j^3 - d_j)}{n^3 - n}}$$

D_j is the number of ties at $j = 1 \dots k$, where k is the number of different values of the response variable, which follows a Chi-square distribution with $r-1$ degrees of freedom.

3. RESULTS AND DISCUSSION

3.1. Analysis of Variance

In Table 1, the analysis of variance with respect to the effect of treatments on reproductive variables is presented, where H represents the value of the applied test and the p value the probability level. In this trial, the genetic factor was randomized as part of the experimental error. As expected, PPF similar to % FRCF5 was not statistically different between treatments. As we know, the genetic control of PPF is relatively high, which explains the relatively low difference between the treatments.

3.2. NFL

Respect NFL, a significant difference was found between the means of the treatments ($P = 0.0002$) (Table 1), where T2 treatment (without pruning and with stand-thinning per line) had the highest NFL per plant as shown in Fig. 2a. Plants pruned and stand-thinned (treatments T3 and T4) produced fewer flowers per plant: 1829.63 and 1415.63, respectively; results that contrast with those of Abanto *et al.* [13], who in pruned plants of 10 years found a production of 8462.77 flowers/

Table 1: Summary of variance analysis for reproductive descriptors of camu-camu by Kruskal-Wallis test.

Variables	Treatments	N	Medias	SD	H	P
Number of flowers	1	8	6304.75	6541.23	19.22	0.0002
	2	8	14720.75	8145.11		
	3	8	1829.63	1199.33		
	4	8	1415.63	1297.62		
Number of fruits in phase 3	1	8	213.00	215.47	14.57	0.0022
	2	8	2150.13	2823.98		
	3	8	189.88	128.45		
	4	8	267.63	171.58		
Number of fruits in phase 5	1	8	53.38	50.95	16.54	0.0009
	2	8	737.38	845.92		
	3	8	61.75	53.14		
	4	8	59.63	70.18		
% fallen fruits in phase 3	1	8	95.72	2.60	16.37	0.0010
	2	8	87.95	9.49		
	3	8	87.32	7.91		
	4	8	78.40	7.80		
% fallen fruits in phase 5	1	8	26.41	15.15	4.15	0.2459
	2	8	24.43	14.27		
	3	8	28.97	17.91		
	4	8	14.78	9.17		
Weight of fruit	1	8	6.54	0.51	1.96	0.5793
	2	8	7.00	0.70		
	3	8	7.03	1.22		
	4	8	6.79	0.67		
Fruit yield	1	8	338.88	324.35	16.37	0.0010
	2	8	5310.38	6387.39		
	3	8	430.36	376.43		
	4	8	395.69	444.45		

$\alpha=0.05$.

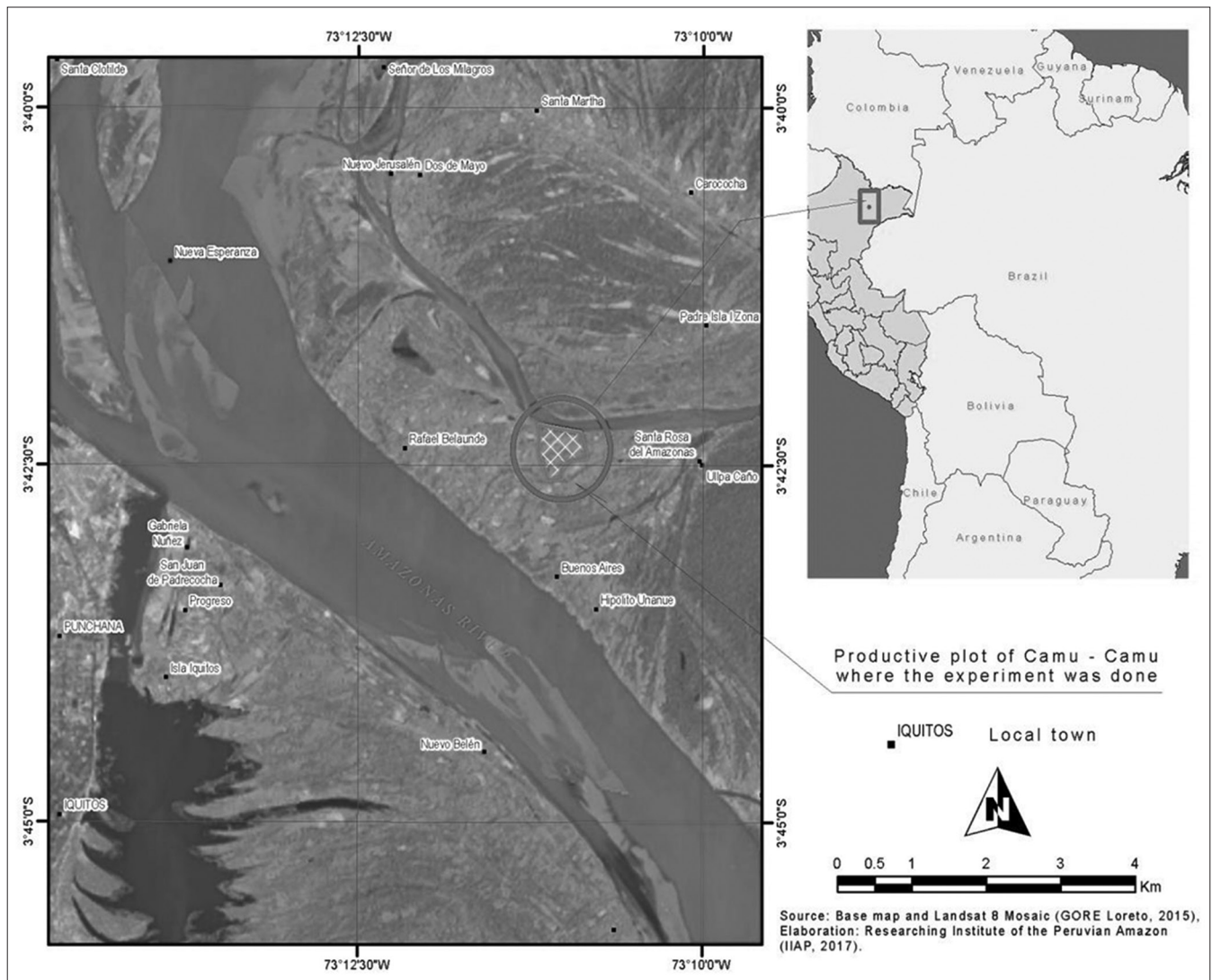


Fig. 1: Location map of experimental field.

plant. It should be noted that, in the first case, the lower yield obtained would be explained by the lower ramification as a consequence of the prolonged time under the system of higher density with excess of shade added to the negative impact of pruning in the short term.

3.3. NFRF3 and NFRF5

In Table 1, for NFRF3, it is observed that there is a statistically significant difference between the treatments ($P < 0.05$). The median test showed two homogeneous groups, where the treatments with pruning and stand-thinning (T3 and T4) are statistically the same, regardless of the type of stand-thinning applied (in line and selective). The second group is the T2 that is statistically different and superior to the other treatments (Fig. 2b). Furthermore, in T3 and T4, there were significantly lower amounts of fruit in phase 3, with averages of 189.88 and 267.63 fruits, respectively; While in T2 (without pruning and with stand-thinning per line), a significantly higher quantity of 2150.13 fruits was counted. Very inferior and contradictory results to those found in the same phenological phase by Abanto *et al.* [13] with 5805.28 fruits packed in pruned plants compared to the controls; result coincident with the assertion of Quijada *et al.* [17], who argue that fructification pruning induces flowering and fruit formation in guava.

In phase 5, evaluating number of fruits/plants, it was also observed a significant statistical difference between treatments ($P < 0.05$) and superiority of T2 (Fig. 2c).

The trend of the NFRF5 continued in favor of T2 with 737.38 fruits/plant, while in pruned plants (T3 and T4), 61.75 and 59.64 were obtained very close to the control with 53.38 fruits/plant. The results indicate that pruning affected the flowering and fruiting phenology, while stand-thinning per line had a markedly positive impact. Possibly, fruiting prunings such as those practised in T3 and T4 treatments should be carried out at an appropriate time after harvesting. In this study, pruning was applied 30 days after the harvest, which may not be the best time to harvest crops in the short term. On the other hand, authors affirm that the pruning part of the floral buds is removed, which results in a significant reduction of fruit [12,18].

3.4. % FRCF3 and % FRCF5

In Table 1, the Kruskal-Wallis analysis of variance shows highly significant differences between treatments ($P < 0.05$), with the effect of pruning and stand-thinning on the percentage of fruits falling to phase 3. The test of medians speared one group (treatments T2, T3

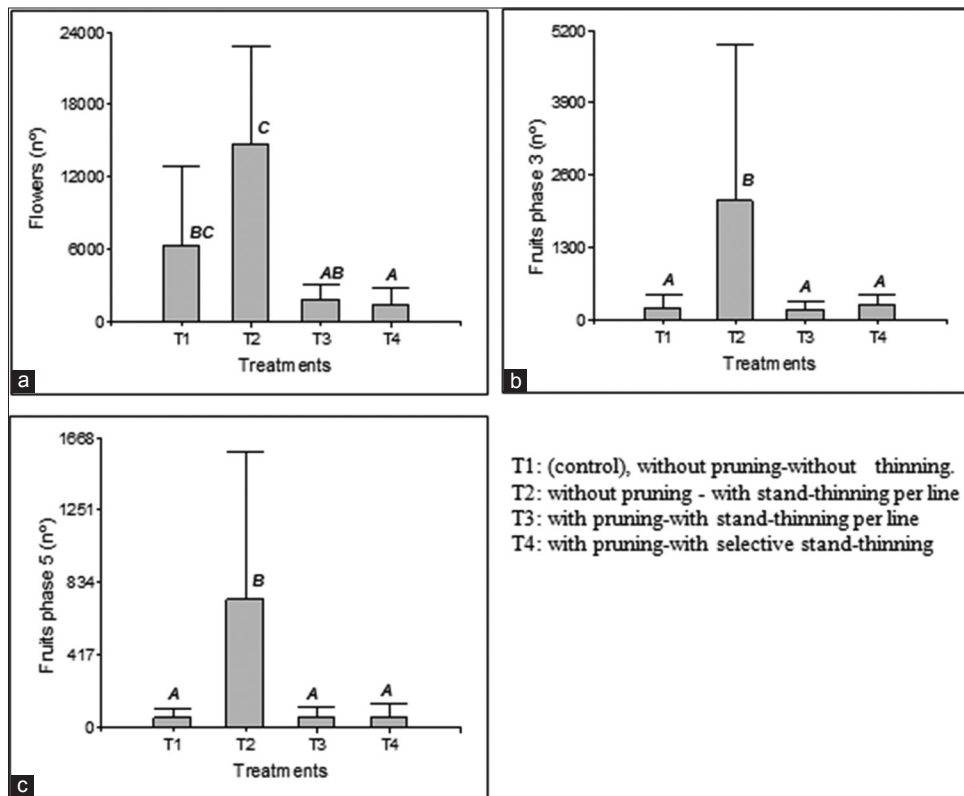


Fig. 2: Effect of pruning and stand-thinning treatments on flowering and fruiting of adult camu-camu plants. (a) On the number of flowers. (b) On the number of fruits in phase 3. (c) On the number of fruits in phase 5. (Each point represents the average of 8 repetitions. Equal letters indicate that there is no significant difference between treatments).

and T4) indicating that they are statistically homogeneous, while T1 presented the highest percentage of fruit drop, differs statistically from the other treatments (Fig. 3a).

The drop of fruits in phase 3 is attributed to physiological and environmental factors. The greatest fall of small fruits occurred in the first 4 weeks of the beginning of the fruiting, where the control had a 95.72% fall, much more than in pruning and stand-thinning treatments (Fig. 3a). This response corroborates the results found by Farro and Pinedo [17], with 94-95.79% of fall and considered as critical phase of small green fruit fall during the first 4 weeks of fruiting.

In this variable, no differences were found between treatments ($P > 0.05$) (Table 1). Fig. 3b showed the percentage of fallen fruit in phase 5 (in relation to phase 3), where T4 recorded the lowest fall percentage.

Unlike fruit drop to phase 3, there were no statistically significant differences of fallen fruit between treatments of the percentage to phase 5 (Table 1 and Fig. 3). This difference in the level of fallen fruit between phases 3 and 5 could be explained by climatic, nutritional, or pest factors, which were not studied in this thesis.

3.5. PPFR

For PPFR, analysis of variance (Table 1) shows that there is no statistically significant difference between the treatments ($P > 0.05$). In Fig. 4a, it can be seen that the T2 (without pruning and with stand-thinning per line) presents a slightly higher PPFR.

In the analysis of non-parametric variance for mean fruit weight, no significant differences were found between treatments (Table 1). The

average values of 7.00 and 7.03 g were lower than those found by Farro and Pinedo [17] with an average of 8.9 g and Paredes [19] with an average of 9.24. Probably, the less level of genetic selection of plants studied, added to the excess shading, has influenced to have fruits of less weight. Shiva and Tanka [12] reported for the case of guava (*P. guajava*) that there was a significant increase in fruit size with a higher level of pruning.

3.6. RFR

For RFR, according to the Kruskal-Wallis test, we found that there are highly significant differences between treatments, with a value of $P = 0.001$ (Table 1). Fig. 4b shows that the median test divides the treatments into two groups, where the treatments with pruning and stand-thinning (T3 and T4) are statistically the same, regardless of the type of stand-thinning applied. While T2 (without pruning and with stand-thinning per line) is distinguished by a statistically superior performance compared to the other treatments. The positive effect of T2 treatment resulted in the best RFR with 5310.38 g/pl, while the control produced 338.88 g/pl which did not differ statistically with pruning treatments. These results agree with Marini [18], who stated that the yield of pruned plants is almost always less than the unpruned, but what the quality and size of fruit are improved by this practice.

Research work on pruning and stand-thinning in forest plantations carried out by Espinosa *et al.* [20], Ferrere *et al.*, [21] and Martiarena *et al.* [22] reported that the controls were always inferior to the treatments handled, bearing in mind that the authors mentioned above treated to improve the performance and quality of the wood.

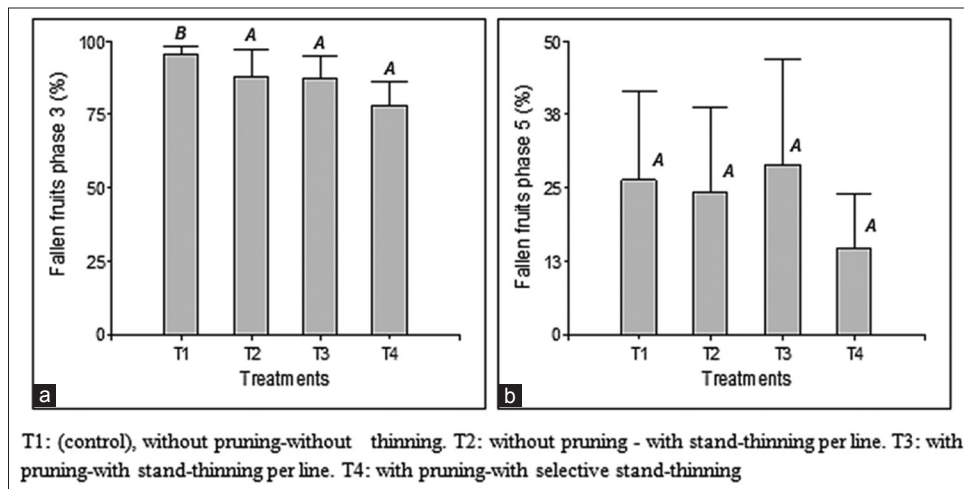


Fig. 3: Effect of pruning and stand-thinning on fruit fall in camu-camu, (a) percentage of fallen fruits to phase 3, and (b) percentage of fruits fallen in phase 5 (treatments with the same letter are not statistically different).

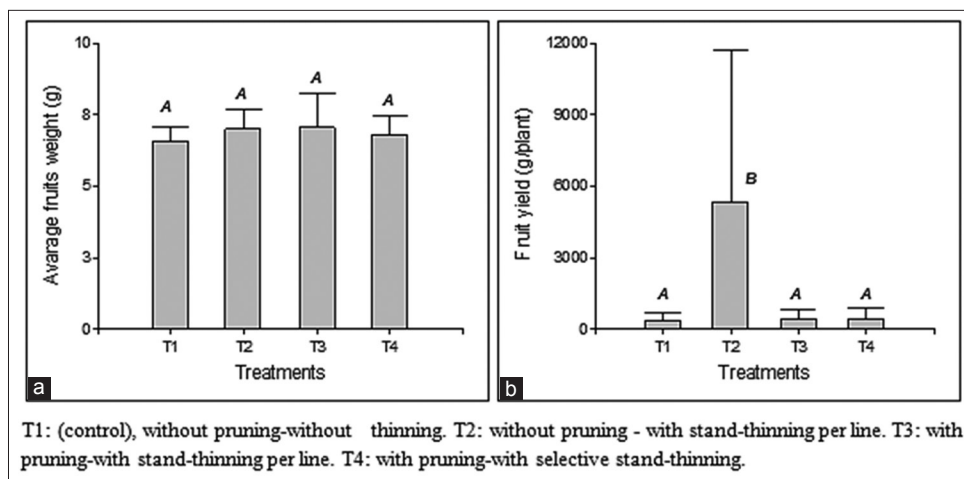


Fig. 4: Effect of pruning and stand-thinning on the reproductive characteristics of camu-camu. (a) Average fruit weight where the same letters indicate that there is no significant statistical difference, (b) fruit yield (different letters indicate that there is significant statistical difference between treatments) (Table 1).

4. CONCLUSION

The T2 treatment (in-line stand-thinning system without pruning) was efficient to significantly increase RFR, whose superiority was observed from the beginning with a greater NFL and fruits in phases 3 and 5. Even in the short term of 10 months of this research.

No significant statistical difference was found for the PFR between the treatments under the study, but it was observed that, in treatments with pruning and stand-thinning, the PFR was higher than the control. It was evidenced that pruning although it was superficial (15 cm from the end) reduced RFR.

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