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Evaluation of weed control techniques in Schizolobium parahyba plantations: Impact on sustainable natural regeneration

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***Abstract* — The study evaluated the initial growth of Schizolobium parahyba under different weed control techniques, both crown and parallel. A 2A × 3B completely randomized block design was used, where A represents the distribution of vegetative material (around the canopy and parallel to the planting lines) and B the canopy radius (50 cm, 75 cm and 100 cm). Twelve treatment plots and one control plot were established. Height, diameter, number of leaves and survival were measured from the second month onwards, with a periodicity of 30 days. Among the findings. Survival did not depend on the radius or distribution of the material, since the control plot did not show the lowest yield. It is noteworthy that weed control favored growth, being the treatment with 50 cm crowns and vegetative material around them the one that obtained the best results in all the variables analyzed.**

Keywords: **Schizolobium parahyba; dasometric variables; seedling survival; weeds; sustainable natural regeneration.**

***Resumen* — El estudio evaluó el crecimiento inicial de Schizolobium parahyba bajo diferentes técnicas de control de malezas. Se utilizó un diseño de bloques completamente aleatorizados 2A × 3B, en el que A representa la distribución del material vegetativo (alrededor del dosel y paralelo a las líneas de plantación) y B el radio del dosel (50 cm, 75 cm y 100 cm). Se establecieron doce parcelas de tratamiento y una de control. La altura, el diámetro, el número de hojas y la supervivencia se midieron a partir del segundo mes, con evaluaciones cada 30 días. La supervivencia no dependió del radio ni de la distribución del material, ya que la parcela control no mostró el menor rendimiento. Sin embargo, el control de malas hierbas favoreció el crecimiento, siendo el tratamiento con coronas de 50 cm y material vegetativo a su alrededor el que mejores resultados obtuvo en todas las variables analizadas.**

Palabras Clave: **Schizolobium parahyba; variables dasométricas; supervivencia de plántulas; arvenses; regeneración natural sostenible.**

I. INTRODUCTION

PACHACO (Schizolobium parahyba), a leguminous species native to the tropical rainforests of South America, has attracted the attention of researchers and foresters for its potential and rapid growth. The diversity of use, economic value and land management of the species has promoted the expansion of its cultivation in the recovery of degraded areas [1], [2], [3]. Thus, in disturbed lands it can reach large dimensions in a short time, becoming an important species in forest ecology or agroforestry systems [4], [5], [6]. Studies have shown that its growth patterns are influenced by climatic conditions such as photoperiod, temperature and precipitation [7], [8].

Naturally, the great advantages of forest plantations are unbeatable, as long as there are favorable conditions [9]. Within this framework, Piotto [10] found that S. parahyba presented excellent growth under mixed conditions, however, within his findings he determined that the variation within the same plot generated high mortality rates in pure and mixed plantations. Hence, in [11], [12] the various factors that influenced the growth of pachaco were studied, such as: soil type, water availability, competition with other species, height, stem diameter and climatic conditions.

From other perspectives, the growth of Schizolobium parahyba is discussed in different aspects due to its expansion as a tropical species. For example: in [13], [14] , topics related to root depths were studied, since the influence of its growth is fundamentally rooted in climatic conditions. In [15] the quality

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of Schizolobium Parahyba (vell.) S.F. Blake seedlings was evaluated under different levels of shade in nursery stages. Despite the fertilization limitations in the trial, it was not conditioned for afforestation and restoration purposes. The quality index obtained (0.33 with 0 % shade level) was above the minimum threshold (0.22). In [16], vegetative propagation by field grafting and mound layering techniques was studied. Given the high survival rate of grafted plants indicated the success of graft union, differentiation of new vascular tissue and formation of a vascular system for vegetative growth. Mound rooting was also satisfactory as it was treated with IBA (indole-3-butyric acid). While in [17] growth regulators for multiplication, elongation and rooting in vitro were evaluated in order to obtain information on cloning via micropropagation of Schizolobium parahyba. Their results showed that in in vitro multiplication and elongation, the higher the dose of cytokinin applied, the higher the shoot proliferation per explant and the lower the mean explant length.

The focus of this work is on seedling growth and competition with other species (weeds) for soil nutrients and its impact on sustainable natural regeneration. Hence, the proposed approach is related to similar works developed in [11], [12], [16]. The added value of the proposal is the self and ecological sustainability of the seedlings. In the work presented here we will induce different configurations of arvenses (circular and parallel) that will be used to assess the level of survival of S. parahyba. In this regard, the control by means of arbenses was defined both in the formation of crowns (circles) and in the distribution of vegetative material, its application allowed estimating the survival of seedlings in plantations of S. parahyba. As the main initial result, it was possible to verify by means of Tukey's test that the survival level has a high sustainable regeneration when the crown radius is 50 and 75 cm.

The hypothesis proposed for this work is: There are no significant differences in the growth and development of S. parahyba in the initial stage of planting, in the face of weed control (weed control). The main objective of this work is to examine the different treatments of weed control techniques to determine the adequate conditions for the growth of Schizolobium parahyba. Therefore, the research questions that answer the objective are: i) What effect do weed control techniques have on initial growth and survival; ii) Which treatment has been effective in survival; iii) Which treatment in statistical terms was determinant for survival; iv) Which treatment in statistical terms was determinant for survival; v) Which treatment has been effective in survival; vi) Which treatment in statistical terms was determinant for survival; vii) Which treatment has been effective in survival; and viii) Which treatment in statistical terms was determinant for survival.

The paper is organized as follows: The first section, is related to the introduction and related works. The second section establishes the work methodology and the application of statistical methods for the verification of the assumptions of weed control in plantations. The third section refers to the results of the study. The fourth section is associated with the discussion of the findings and the contrast with analogous works. The fifth section contains the conclusions of the study.

II. METHODOLOGY

A. Study area

The present study was carried out in the district of "Agua Clara" belonging to the Quinindé Canton of the Province of Esmeraldas, Ecuador. The geographical coordinates are: Latitude: 0.333333, Longitude: -79.2833, Altitude: 85 meters above sea level. The climate of the area described is rainy-tropical, its average temperature is 27 ° Celsius. A wet day is a day with at least 1 millimeter of liquid or liquid equivalent precipitation. The probability of a wet day during the summer decreases very fast, starting at 37 % and ending at 12 %. For reference, the highest probability of the year of having a wet day is 78 % on February 10, and the lowest probability is 9 % on August 7.

The probability of a given day being wet decreases in June, and decreases from 99 % to 94 % over the course of the month. For reference, on April 12, the hottest day of the year, there are sultry conditions 100 % of the time, while on September 3, the least sultry day of the year, there are sultry conditions 65 % of the time.

B. Experimental design

To carry out the study, completely randomized blocks were designed (DBCA), with a factorial arrangement of the form 2A x 3B with two replications and a control plot, where A is the form of distribution of the vegetative material produced at the time of clearing the land, which was located around the crown and parallel to the planting lines; and, on the other hand, B is the radius of the crowns which was 50 cm, 75 cm and 100 cm (See Annexes, Table V). Then, 13 plots were established: 12 corresponding to the treatment and one for control. The plot measures were 25 m x 20 m (500 m²), 30 individuals per plot. The S. parahyba plantation was established at a distance of 3 x 4 m, in a total area of 6.6 hectares. That is, the area used was 6500 m² and 390 individuals. On the other hand, and no less important was the weed control carried out mechanically using a weed cutter (Moto scythe) at 60-day intervals. In the case of the control plot, it was operated in the usual way by the owner, with intervals of three or four months.

C. Interventions

In order to isolate the effect of weed control on the dasometric variables of pachaco seedlings and to evaluate the impact of different crown radii on growth, an experimental design was established with four replicates for each treatment. At the beginning of the study, crowns of 50, 75 and 100 cm radius were formed around each seedling, eliminating competing vegetation manually. At the same time, a weed control program was implemented with a variable frequency of 30 to 60 days, depending on climatic conditions. The plant material resulting from both practices (weed control and crown formation) was distributed parallel to the planting lines and on the edges of the crowns, avoiding regrowth and minimizing its impact on seedling growth.

D. Methods for evaluation

For the estimation of survival, it was necessary to count the number of standing individuals for each treatment in both the initial and final stages. According to Eq.1 [18] the level of survival can be determined from the following mathematical expression:

$$p = \frac{\sum_{i=1}^{n} a_i}{\sum_{i=1}^{n} m_i} \cdot 100 \qquad (1)$$

Where: $\sum_{i=1}^{n}$ is the sum of the data according to “a” or “m”; p: is the proportion of live trees; is the number of live plants in sample site “i”; is the number of live and dead plants in sample site “i”. When approaching the statistical test for the verification of the treatments, they were approached in two phases: The first, descriptive analysis of the dasometric variables (diameter, height and number of leaves) was used. The second, using analysis of variance (ADEVA) to compare the means and verify the existence of significant differences between treatments, as shown in Table I. For this purpose, the Tukey test [19] was applied to compare individual means (p<=0.05). The experimental data were tabulated and processed with the IBM-SPSS-Stastistics 22 program (Free Trial Version).

TABLE I
ANALYSIS OF VARIANCE FOR A TWO-FACTOR EXPERIMENTAL DESIGN IN THE APPLICATION OF TREATMENTS IN THE SPECIES S. PARAHYBA

Source of Variation	**Sum of Squares**	**Degrees of Freedom**	**Mean Squares**	**Estimated F* value**
Treatments	SCT	$k-1$	$S_1^2 = \frac{SCT}{k-1}$	$f_1 = \frac{S_1^2}{S^2}$
Blocks	SCB	$b-1$	$S_2^2 = \frac{SCB}{b-1}$	
Residual	SCE	$(k-1)(b-1)$	$S^2 = \frac{SCE}{(k-1)(b-1)}$	
Total	STC	$kb-1$		

SCT: Sum of squares for treatments; **SCB:** Sum of squares for blocks. **SCE:** Sum of squares for error; **STC:** Total sum of squares.

III. RESULTS

In response to the research questions posed and objectives established in this work. The main results obtained can be highlighted. The survival rate, generic growth and the effect of weed control techniques on the pachaco plantation were studied.

The first research question was answered: What effect do weed control techniques have on initial growth and survival? During the first years, pachaco shows exceptionally rapid growth in height and diameter, which allows it to reach considerable heights in a short time. Growth in height, diameter and number of leaves. Pachaco (Schizolobium parahyba) is a fast-growing and highly adaptable forest species. Figures 1, 2 and 3 are the average values collected from this work. The data can be found in the annexes section described in Table VI, Table VII and Table VIII.

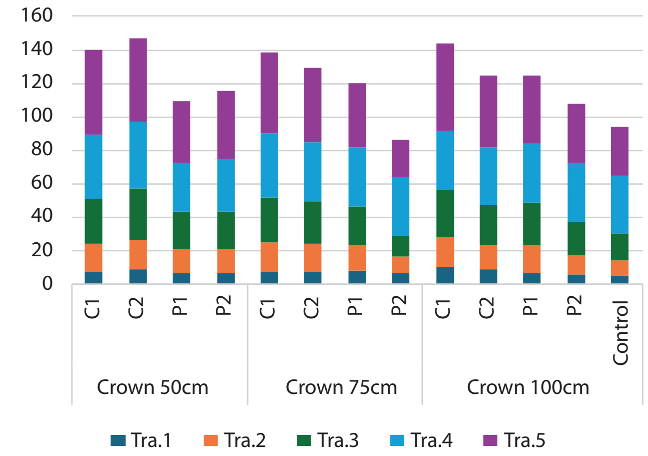

Fig. 1. Projection of the average base diameter, the abscissa shows the arrangements of the vegetative material. C corresponds to the crown arrangement and P to the parallel vegetative arrangement.

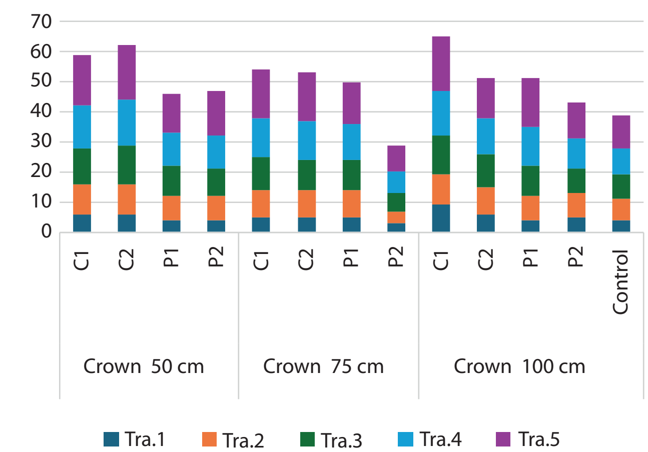

Fig. 2. Projection of the average height, the abscissa shows the arrangement of the vegetative material. C corresponds to the crown arrangement.

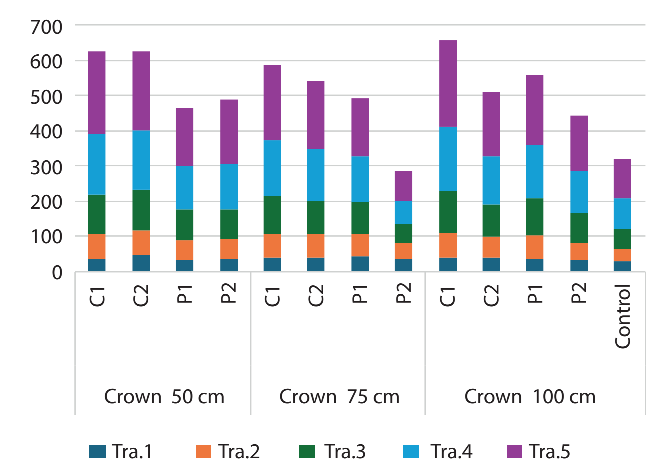

Fig. 3. Projection of the number of leaves, the abscissa shows the arrangement of the vegetative material. C corresponds to the crown arrangement and P to the parallel vegetative arrangement.

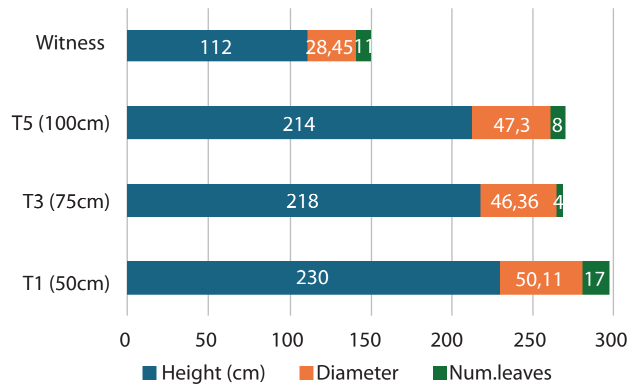

Fig. 4. Dasometric results of pachaco seedlings.

Figure 4 shows the dasometric summary of the field work carried out, the horizontal bars correspond to each treatment, with treatment 1 with a 50 cm crown being the one that reached the greatest height, diameter and number of leaves. However, Tables II, III and IV, where the calculation of Tukey's statistics is presented, will allow us to know the treatment with the best performance.

TABLE II
AVERAGE HEIGHT (CENTIMETERS) OF S. PARAHYBA RELATED TO CROWN RADIUS AND DISTRIBUTION OF VEGETATIVE MATERIAL

Tukey's test for height (centimeters)				
Treatments	Subset for alpha = 0,05			
	1	2	3	4
Tra.1	230.45 a↑			
Tra.3		214.47 ab		
Tra.5		203.58 abc		
Tra.6			183.28 bc	
Tra.2			174.97 c	
Tra.4				128.14 d
Witness				111.96 d

↑ Means with different letters show significant statistical differences according to Tukey's test $p > 0,05$.

It can be observed in Table II that, after 120 days of data recording, the height shows significant statistical differences between each treatment, with the influence of both crown size and the distribution of vegetative material on the increase in height. On the other hand, the control plot was the one that presented the lowest growth in height with an average of 111.96 cm, although the average growth was 128.14 cm in individuals of the plot of Treatment 4, these two plots had a statistically similar behavior.

Likewise, the plot with Treatment 1, the average height was 230.45 cm, this treatment being the one with the highest growth in height compared to the rest of the treatments; however, it behaves statistically similar to the plot with Treatment 5, which had a height of 214.17 cm at the end of the data collection.

TABLE III
MEAN DIAMETER (MILLIMETERS) OF S. PARAHYBA RELATED TO CROWN RADIUS AND DISTRIBUTION OF VEGETATIVE MATERIAL

Tukey's test for diameter (millimeters)			
Treatments	Subset for alpha = 0,05		
	1	2	3
Tra.1	50.11 a↑		
Tra.3	47.3 a		
Tra.5	46.36 a		
Tra.6		39.54 b	
Tra.2		28.45 c	
Tra.4			38.93 b
Witness			31.2 c

↑ Means with different letters show statistical differences according to Tukey's test at p > 0.05 probability.

Table III shows that, after 120 days from the beginning of data recording, plant diameter is different for all treatments. In addition, it is noted that all plots show significant statistical differences between them. This suggests that there is influence of both crown size and vegetative material distribution in relation to the increase of the dasometric variable, which in this case plant diameter.

It is highlighted that the control plot registered the lowest growth in diameter, with an average of 28.45 mm, despite the fact that the average growth was 31.2 mm in the plots with Tra.4, these two plots behaved statistically similar. In addition, it is mentioned that the plot with Tra.1, had a diameter growth of 50.11 mm, in this plot shows a statistically similar behavior to the plot with Tra.5, which had a diameter of 47.30 mm and 46.36 mm (Table III).

TABLE IV
MEAN NUMBER OF LEAVES FOR S. PARAHYBA RELATED TO CROWN RADIUS AND DISTRIBUTION OF VEGETATIVE MATERIAL.

Tukey's test for diameter (millimeters)				
Treatments	Subset for alpha =0.05			
	1	2	3	4
Tra.1	17.26 a↑			
Tra.3		16.28 ab		
Tra.5		15.58 abc		
Tra.6			14.3bc	
Tra.2			1391 c	
Tra.4				11.43 d
Witness				10.67 d

↑ Means with different letters show statistical differences according to Tukey's test.

Table IV provides a detailed description of how different treatments, specifically crown ratio and vegetative material distribution, influenced the number of leaves after a 120-day cycle, Furthermore, it is highlighted that the configured plots presented statistically significant differences. Hence, the influence of both crown size and vegetative material distribution in relation to the increase in leaf quantity is estimated.

On the other hand, the control plot (control) presented less quantity of leaves with a mean of 10.67 leaves, although the mean growth in the individuals belonging to the plots with a crown size of 75 cm with distribution of the vegetative material parallel to the planting line (Tra.4) was 11.43; these two plots behaved statistically the same. Similarly, the plot with a crown size of 50 cm, with distribution of vegetative material around the crown (Tra.1), was 17.26; this plot behaved statistically similar to the plot with a crown size of 75 cm and 100 cm with distribution of vegetative material around the crown (Tra.3 and Tra.5), with a number of leaves of 16.28 and 15.58 at the end of the data collection.

As an answer to the third question posed, the Tukey statistical test with a p-value > 0.05 shows that treatment 1 stands out in height, diameter and number of leaves. In this sense, the treatments applied in this study show that it has a significant effect on the growth and development of Schizolobium parahyba seedlings in its initial stage, therefore, the hypothesis raised in this research is rejected.

IV. DISCUSSION

Plant survival is influenced by weed control and favorable conditions for pachaco growth. For this reason, it is essential to implement integrated management that combines preventive, cultural, mechanical and, in some cases, chemical methods. The use of crowns and vegetative material as part of weed control in the research plots maintained constant pachaco survival. Thus, the control plot had a slight decrease in its survival values compared to the treatments.

Analogous to our results in [20], the survival of Eucalyptus grandis trees was studied where the type of arvense was similar to that used in our study. It was specified that survival with competing plant species in plantations has little effect. However, the same type of weed in the results of this study shows that the survival rate in the control plot was 80 %. While, the other plots showed lower results 58.33 % and 65 % respectively. In spite of the fact that ant attack was an evident factor in the plots.

Another factor, no less important and which influenced the survival rate of forest plantations, was the stress generated to the seedlings due to water shortage. In addition to the copious presence of weeds, which generally compete with the plantations in their initial state for water and this negatively affects their growth. The plots at the beginning of the experimental record had a height between 33 to 40 cm, and applying the different distributions of vegetative material, the record at 120 days after the first record of the research (180 days from the establishment of the plantation), the height was found to be between 98 to 172 cm. Likewise, in [21], [13] showed good survival and excellent growth rates during the first year of establishment of the Schizolobium parabyba plantation, although later the trees die for no apparent reason, but for lack of adaptation to the conditions and competitions of the plantation.

As observed in the field, the natural regeneration of Schizolobium parabyba grows excellently and normally forms isolated trees or in small groups. Thus, the realization of crowns and their respective arrangement of vegetative material resulting from weed control is a factor that benefits the height growth of the species. In this regard, at the conclusion of the research, each treatment exhibited a larger diameter than the control plot, which reached an average of 28.45 mm. This set of evidence is close to the results obtained by Melo [22] where he stated that the higher ratios observed at lower planting density are favorable conditions for growth, since there is less competition for soil nutrients and water.

On the other hand, the diametric study of the seedlings in the plots at the beginning of this work showed diameters ranging from 6.25 to 9.58 millimeters. However, when the crowns and subsequent application of different arrangements of the vegetative material resulting from weed control were carried out 120 days after the first record of the research (210 days after the establishment of the plantation), a diametric range was observed in the seedlings from 30.45 mm to 50.11 mm, that is, in the first case the diameter increased by 487 % and, in the second, it increased by 523 %. It is notorious that applying weed control, in general, increases diameter growth.

Among the factors of importance in plantations of S. parahyba, diameter was considered relevant. Chronologically, two stages were observed from the initial stage: 60 and 90 calendar days. In the first section, there was an increase in diameter where the mean was 199 % (7.67 mm increased to 15.29 mm). In the second tranche, the mean compared to the control plot increased by 178 % (5.20 mm increased to 9.29 mm). These findings clarify that establishing plots with different crowns and distribution of vegetative material favors the increase in diameter due to the applied weed control. When comparing these evidence, it stands out, for example, that a weak control of weeds leads to a loss of plantation diameter. According to [23], the increase in diameter obtained in the same sections was 119 %. However, in the work presented here, these values are exceeded between 6 and 8 times.

The number of leaves of the plots with different crown sizes and different arrangements of vegetative material obtained values between 14 and 17, which were higher than the control plot that obtained an average of 11 leaves. In this sense, Carranza-Patiño [13] confirms that the increase in the number of leaves and biomass is a significant indicator of healthy plant growth. In addition, Borda [24] indicated that the number of leaves increases with respect to the weed control (12 leaves). While, those with higher intensity of weed control averaged between 17 and 18 leaves.

On the other hand, Quiroz [25] established a direct correlation between leaf density and plant growth vigor. A greater number of leaves increases photosynthetic capacity and transpiration surface, which stimulates the development of a more extensive root system. The results of the research presented here corroborate this statement, showing a positive relationship between the number of leaves and the growth in height and diameter of the plants. This suggests that leaf density is a reliable indicator of the growth and development potential of plant species.

The survival rate did not depend on the treatments applied in this research, this is reflected due to the variability of this and that the control plot did not obtain the lowest survival record, when compared with the different treatments applied, however there was an attack of ants of the genus Att, which is a relevant factor that could have influenced the survival of the seedlings, this highlights the importance of considering and properly manage the factors that may affect the ability of seedlings to establish and develop.

As a limitation to this research, it was necessary to consider as part of the treatments the level of vulnerability of the seedlings. For example: ants of the genus Att could be behind the level of survival [20].

V. CONCLUSIONS

In response to the research questions and hypotheses posed. The dasometric variables, such as diameter, height and number of leaves. They were determinant for the evaluation of the different weed control treatments. Therefore, the use of crowns with different radii and distribution of vegetative material are determinant for the growth and development of pachaco plants. The control plot lacked low yield compared to the rest. Therefore, the impact of sustainable regeneration through weed control was positive by avoiding dependence on chemical herbicides. The 50 cm radius plot had a better yield. One of the limitations of this work was related to the constant monitoring of possible biotic and abiotic threats. As future work, an integrated management of external factors is suggested to permanently monitor possible biotic and abiotic threats to minimize their impact on the plantations.

APPENDIX

A. Data Analysis

TABLE V
TYPES OF TREATMENTS ESTABLISHED
FOR SCHIZOLOBIUM PARAHYBA PLANTATION

Trataments	Crown radius (cm)
Tra.1	50*
Tra.2	50**
Tra.3	75*
Tra.4	75**
Tra.5	100*
Tra.6	100**
Witness	Habitual

* Distribution of vegetative material around the crown.

** Distribution of vegetative material parallel to the planting line.

TABLE VI
AVERAGE GROWTH OF BASE DIAMETER IN MILLIMETERS,
C1 ARRANGEMENT OF VEGETATIVE MATERIAL
IN CIRCULAR FORM AND P1 ARRANGEMENT OF VEGETATIVE
MATERIAL IN PARALLEL FORM.

Crown	Config	Tra.1	Tra.2	Tra.3	Tra.4	Tra.5
50cm	C1	7.27	16.99	27.09	38.18	50.13
	C2	9.19	17.81	29.93	40.01	50.1
	P1	6.97	14.07	22.1	29.48	36.87
	P2	6.58	14.34	22.72	31.6	40.49
75cm	C1	7.61	17.25	27.43	37.77	48.12
	C2	7.81	16.5	25.34	34.97	44.6
	P1	8.26	15.22	23.17	34.97	38.42
	P2	6.69	9.91	12.23	34.97	22.49
100cm	C1	10.27	17.97	28.43	34.97	51.97
	C2	8.9	14.68	23.48	34.97	42.62
	P1	6.76	16.7	25.77	34.97	40.68
	P2	5.74	12	19.77	34.97	35.69
	Control	5.2	9.29	15.78	34.97	28.45

The values presented in Tables V and VI specify the configuration and average values of the treatments used. Thus, Table V shows the configuration of each of the treatments designed for the pachaco study process. Table VI details the configurations made at the crown level and the arrangement of the vegetative material in parallel.

B. Data collection of the different dasometric variables under study.

TABLE VII
AVERAGE GROWTH IN HEIGHT, C1 ARRANGEMENT
OF THE VEGETATIVE MATERIAL IN A CIRCULAR SHAPE
AND P1 ARRANGEMENT OF THE VEGETATIVE MATERIAL
IN A PARALLEL SHAPE

Crown	Config	Tra.1	Tra.2	Tra.3	Tra.4	Tra.5
50cm	C1	35	69	113	173	237
	C2	45	70	116	170	223
	P1	33	55	86	126	165
	P2	35	56	83	133	183
75cm	C1	40	67	106	160	215
	C2	40	65	97	145	193
	P1	43	62	91	129	166
	P2	36	45	51	68	84
100cm	C1	38	70	121	183	245
	C2	40	58	91	138	184
	P1	36	66	105	153	197
	P2	31	51	84	120	157
	Control	27	36	58	86	112

Fig. 5. Measurement of tree height.

Fig. 6. Measurement of tree diameter.

Fig. 5 shows the person measuring the height of the tree using a common flexometer. While in Fig. 6 the diameter of another tree is taken using a digital caliper. The collected values are added to databases that serve as input data for applying statistical techniques. As a follow-up of this activity, the data shown in Tables VII and VIII present the average growth in height of pachaco (Table VII) in both types of arrangements. On the other hand, in Table VIII the results refer to the amount of fallen leaves in the arrangements and treatments.

TABLE VIII
NUMBER OF LEAVES, C1 ARRANGEMENT OF VEGETATIVE MATERIAL IN A CIRCULAR SHAPE AND P1 ARRANGEMENT OF VEGETATIVE MATERIAL IN A PARALLEL SHAPE

Crown	**Config**	**Tra.1**	**Tra.2**	**Tra.3**	**Tra.4**	**Tra.5**
50 cm	C1	6	10	12	14	17
	C2	6	10	13	15	18
	P1	4	8	10	11	13
	P2	4	8	9	11	15
75 cm	C1	5	9	11	13	16
	C2	5	9	10	13	16
	P1	5	9	10	12	14
	P2	3	4	6	7	9
100 cm	C1	9	10	13	15	18
	C2	6	9	11	12	13
	P1	4	8	10	13	16
	P2	5	8	8	10	12
	Control	4	7	8	9	11

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