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Original article

Effects of different times and intensities of fructification pruning in camu-camu plants

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Summary

Introduction – **In order to generate more accurate agronomic management practices for the cultivation of camu-camu (*Myrciaria dubia*), a study was conducted to measure the effects of different timings and intensities of the plant fructification pruning.** *Materials and methods* – **The study was conducted following a complete randomized block design in split plot arrangement with four repetitions composed of four plants per experimental unit by treatment. The plots were constituted of 4 pruning times (April, May, June and July of 2014) and the sub-plots by the following pruning intensities: short at 80 cm, medium at 120 cm, and long at 180 cm in height. The shoot number (SN) and shoot length (SL), the numbers of flowering buds (NFB), of small fruits (NSF) and harvested fruits (NHF) were measured. The evolution of some phenological characteristics was also recorded over time.** *Results and discussion* – **Short-pruned trees had smaller numbers of shoots but greater shoot lengths, thus delaying flowering and significantly reducing fruit production. Independently of the pruning season, the camu-camu plants submitted to long pruning or tip removal presented a greater number of shoots, of flowering buds, small fruits and harvested fruits.** *Conclusion* – **Long pruning in camu-camu plants allowed fructification in less time regardless of in which month it was performed and pruning on camu-camu plants stimulated the growth and development of fruitful branches, thus contributing to a sustainable fruit production every year.**

Keywords
Peru, Amazon, camu-camu, *Myrciaria dubia*, fruit quality, harvesting date, tree crop management

Résumé

Effets de l'époque et de l'intensité de la taille de mise à fruit chez le camu camu.

Significance of this study

What is already known on this subject?

- Camu-camu is a native fruit of the Peruvian Amazon in the process of domestication.

What are the new findings?

- Pruning of camu-camu plants at a long height proved to make fructification in less time regardless the season it was performed. Long pruning (at the top) on camu-camu plants stimulated the growth and development of fruitful branches, and allowed a yearly fruit production, whereas pruning at the basis or the middle of the plants significantly delayed fruiting.

What is the expected impact on horticulture?

- The adequate fruit pruning technique transferred to the producers of camu-camu will allow them to obtain crops every year.

Introduction – **Cette étude a été menée dans le but de générer des innovations en gestion agronomique de la culture du camu camu, en particulier pour déterminer les effets de différentes époques et intensités de taille de mise à fruit des plantes.** *Matériel et méthodes* – **L'étude a été conduite selon un modèle expérimental en blocs aléatoires de parcelles divisées en split plot à quatre répétitions, composées de quatre plantes par traitement. Les traitements parcellaires ont été constitués de 4 époques de taille (avril, mai, juin et juillet 2014) et les sous-parcelles par les intensités de taille suivantes: courte à 80 cm, moyenne à 120 cm et longue à 180 cm de hauteur. On a évalué le nombre de pousses (SN) et la longueur des pousses (SL), le nombre de bourgeons fleuris (NFB), de petits fruits (NSF) et de fruits récoltés (NHF). Les caractéristiques phénologiques du comportement des plantes traitées ont été enregistrées sur la durée de l'étude.** *Résultats et discussion* – **Les arbres taillés court ont présenté un nombre de pousses inférieur, mais des longueurs de pousses supérieures, retardant ainsi la floraison et réduisant significativement la**

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production de fruits. Indépendamment de la saison de taille, les plants de camu camu soumis à une taille longue ou à l'enlèvement des bourgeons ont présenté un plus grand nombre de pousses, de boutons fleuris, de petits fruits et de fruits à la récolte. *Conclusion* **– La taille longue des plants de camu camu a permis une mise à fruits plus rapide quelle que soit l'époque à laquelle elle a été effectuée et a stimulé la croissance et le développement de branches fructifères, contribuant ainsi à une production fruitière annuelle durable.**

Mots-clés
Pérou, Amazone, camu camu, *Myrciaria dubia*, qualité fruitière, date de récolte, gestion du verger

Introduction

Fruit culture represents a large part of global agricultural production and contributes in a significant way to the generation of employment and economic income in rural areas (FAO, 2015). Camu-camu (*Myrciaria dubia* HBK McVaugh) is a native species of the Amazon and distinguishes itself as a source of antioxidants due to its high concentration of vitamin C (3,571 mg 100 g^{-1} pulp), which presently represents the Amazonian agro-biodiversity resource with the best prospects on the national and international markets (Abanto *et al*., 2015, 2014a; Rodrigues *et al*., 2001).

From the social and environmental point of view, camu-camu is very important because small-scale producers, who in the vast majority utilize family labor, cultivate it, thus generating employment in the rural setting. On the other hand, as this crop culture is developed on flooding soils, it avoids deforestation of primary and secondary forests.

Due to globalization, camu-camu producers need to cope with the requirements and demands of the national and international market. To this end it is necessary to place emphasis on agronomical management of the culture, in order to obtain greater fruit yield, improve the quality of the product, produce large volumes at low cost and have a product availability that generates confidence in the market. The production of the camu-camu is linked to its flowering and fructification, which may vary as a result of genetic and environmental factors and management of the crop.

Existing plantations of the camu-camu in the region of Ucayali that are more than 15 years old, are characterized by an excess of vegetative growth, due to the high density seeding plants (3 × 3 m; 3 × 2 m; 2.0 × 1.5 m; 1.0 × 1.5 m; 2 × 2 m) and the lack of appropriate agronomic management which has caused the decrease of overall yields, quality traits such as size and color and soluble solids of the fruit, and has caused the increase of pests and diseases (Abanto *et al*., 2014b; Flore and Layne, 1999). Fructification (or production) pruning, one of the adequate techniques to balance the vegetative activity and the reproduction of the fruit tree, consists of the ordered elimination of the aerial structures of the plant to control vegetative growth, improve luminosity and aeration, and stimulate the formation of new fruiting branches in the crown (Navarro and Ramírez, 2010).

According to studies done by Abanto *et al*. (2011, 2014), camu-camu responds very well to out-of-season fructification pruning, permitting the agriculturalist to make well-defined two harvests in 15 months, and this way commercialize the product in the inter-harvest period and at more attractive prices. Notwithstanding the fact that the camu-camu is a fruit-bearing tree which has been cultivated for around 30 years, there is still a lack of investigative works that indicate which is the most appropriate time of the year and intensity or level of pruning cuts to get fruit production and high fruit quality every year.

Inappropriate intervention may provoke a decrease in the fruit production and alter the productive cycle in the following years, as occurs in the *Psidium guajava* L. crop (Gonzalez and Sourd, 1982; Singh *et al*., 2001), where inappropriate fructification pruning negatively affected production.

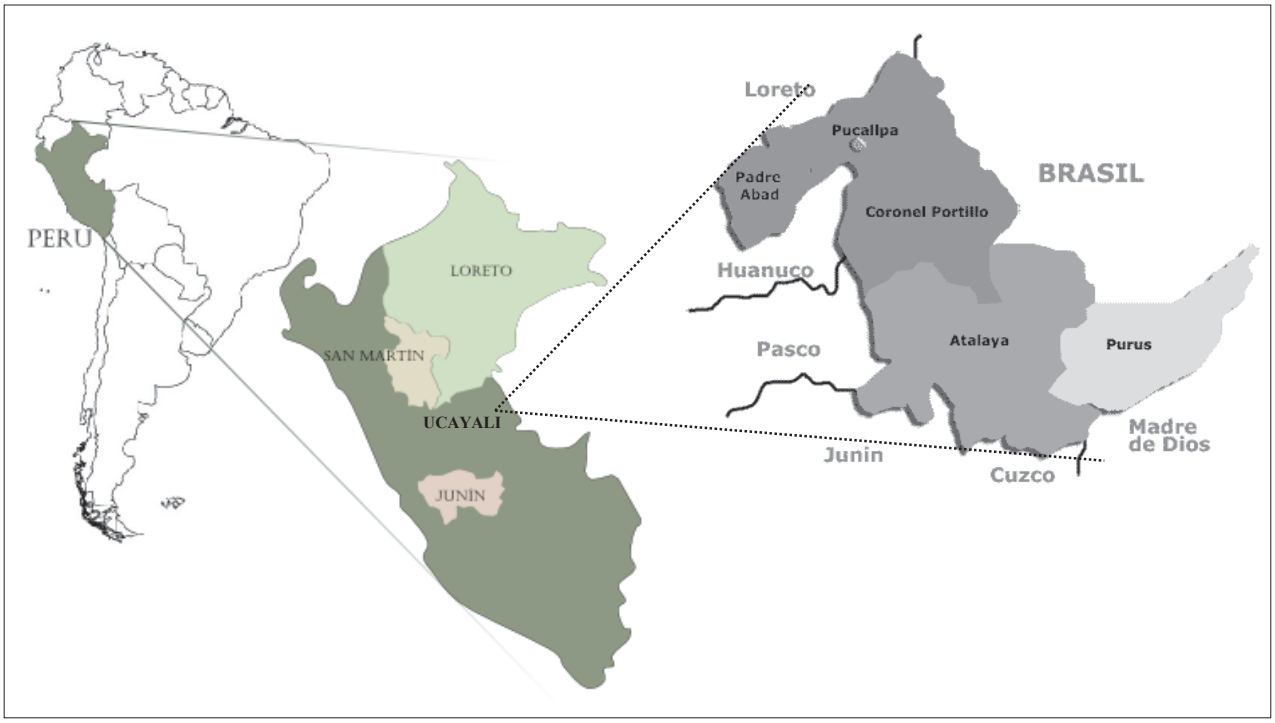

Figure 1. Location of the study-Pucallpa, Ucayali-Peru.

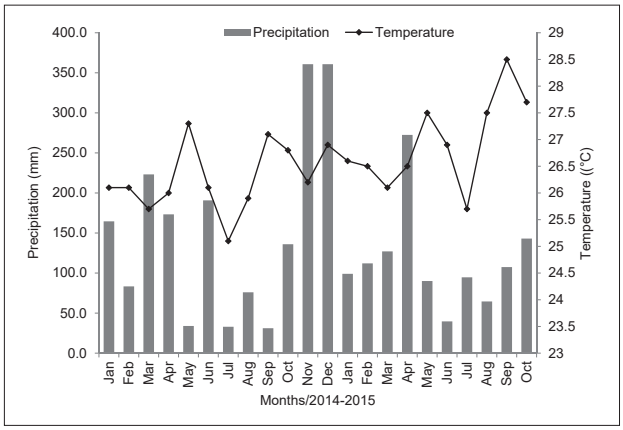

Figure 2. Pluvial precipitation and average temperature during the months of January to December (2014) and from January to October (2015), Yarinacocha, Ucayali, 2014. Source: Pucallpa Meteorological Station 000449-SENAMHI, 2014–2015.

On *Vaccinium myrtillus* it was similarly reported that when a drastic fructification pruning was applied, a higher quality of vegetative branches was obtained and lower quantities of fruit were formed (Albert *et al*., 2010). On the other hand, a pruning of 15 to 20% vegetative growth was applied on mango trees (*Mangifera indica* L.) in production generated an optimal balance between cytokinins and gibberellins which promoted flowering every year (Chadha and Pal, 1985). In order to offer more precise agronomic information to the camu-camu producers, this study was done with the objective of determining the most effective time of year and pruning intensity to obtain a crop every year.

Materials and methods

Location of the study

The present study was done during two fruiting seasons (2014–2015), on a 5-year old camu-camu plantation located at the Dale E. Bandy Research Center of the Institute of Research of the Peruvian Amazon – IIAP, located at 12.4 km of the Federico Basadre Highway, Yarinacocha District, Coronel Portillo Province, Ucayali Region, Peru, situated at 8°22'31''S and 74°34'35''W, at an altitude of 154 m a.s.l. (Figure 1).

The climate is tropical, with warm temperatures throughout the year, classified as an equatorial climate according to the Koppen system. The average annual temperature is 26.0 °C, with maxims of 28.5 °C in August and minimum of 25.7 °C in July. The average maximum temperature is 33.0 °C and the minimum temperature is 21.5 °C. Annual rainfall precipitation is approximately 1,867 mm with higher precipitation between October and April (Figure 2).

Characteristics of the planting of camu-camu

In April of 2014, a 5-year old camu-camu plantation was selected, with a planting distance of 2 × 2 m (2 m between plants and 2 m between rows). They were produced from a seed obtained in 2009 in the Tinta oxbow lake, located on the Putumayo River (Peru-Colombia border). Before initiating the experiment, the plants were 2.5 m in height and 1.5 m in average diameter. Apart from this the plants were never pruned and only manual cleaning and weeding were done.

The soil is an ultisol of a mild acrylic texture, lacking in organic material (1.36%), phosphorus (2.28 ppm) and potassium (0.15 cmol L^{-1}), with a pH of 5.78, aluminium saturation of 38.26% and a cation-exchange capacity (CEC) of 4.18 cmol L^{-1}. Due to limited availability of mineral nutrients in the soil, 300 g dolomite calcium, 3 kg chicken manure, 70 g urea, 100 g potassium chloride and 200 g triple superphosphate were applied in a circle around each plant (López, 2001).

Figure 3. Pruning of camu-camu plants at a height of a) 80 cm, or b) 180 cm, in the IIAP, Peru, April, 2014.

Figure 4. a) Least number of shoots (pruning at a height of 80 cm), b) Largest number of shoots in camu-camu plants (pruning at a height of 180 cm) in the IIAP, Peru, June 2014.

Table 1. Summary of variance analysis of the number of shoots (NS), length of shoots (cm) (LS), number of flowering buds (NFB), number of small fruits (NSF) and number of harvested fruits (NHF) of camu-camu during the 2014 period.

Sources of variation	GL	Mean value squares				
		NS	LS (cm)	NFB	NSF	NHF
Blocks	3	423.13	237.48	35,691.69	6,542.00	3,705.16
Pruning time (PT)	3	2,273.18^{ns}	1,076.06**	170,796.29*	5,781.75^{ns}	2,157.77^{ns}
Residual 1	9	1,168.33	114.10	21,527.98	2,268.84	1,201.67
Pruning intensity (PI)	2	34,564.56**	1,992.13**	1,289,368.52**	183,323.52 **	87,364.27**
PT × PI	6	2,101.87^{ns}	591.93**	170,796.30**	5,781.74^{ns}	2,157.77^{ns}
Residual 2	24	350.31	131.83	25,068.91	3,337.14	1,827.54
CV (%) 1		44.50	24.54	89.52	77.08	81.25
CV (%) 2		38.94	26.37	96.61	93.48	100.20

*, **, ^{ns}: Significant at 5% level, 1% level, not significant, respectively.

Table 2. Number of shoots (NS), length of shoots (LS), number of flowering buds (NFB), due to the effect of the time and intensity of camu-camu pruning during the 2014 period. Values are means of four repetitions composed of four plants per treatment.

Pruning intensities	NS				LS (cm)				NFB			
	Pruning times											
	April	May	June	July	April	May	June	July	April	May	June	July
Short	56 Ab	58 Ab	39 Ab	33 Ab	58.0 Aa	38.0 Aa	30.0 Aa	51.0 Ab	0 Ab	0 Ab	0 Ab	0 Ab
Medium	65 Ab	57 Ab	39 Ab	55 Ab	68.0 Aa	39.0 Ba	37.0 Ba	70.0 Aa	0 Ab	0 Ab	0 Ab	0 Ab
Long	146 Aa	145 Aa	99 Ab	132 Aa	29.0 Ab	29.0 Ab	21.0 Bb	31.0 Ab	831.0 Aa	887.0 Aa	496.0 Ba	703.0 Aa
Average	89	87	59	73	51.6	35.3	36.7	50.7	227.0	295.7	118.7	234.3

For each pruning time (line), the mean values followed by at least one capital letter presented no differences based on the Tukey's test (P<0.05). For each pruning intensity (column) the mean values followed by at least one common letter presented no differences based on the Tukey's test (P<0.05). Four repetitions composed of four plants per experimental unit by treatment.

Experimental design

The study was conducted with the use of a Completely Randomized Block Design (CRBD) in a split plot arrangement with four repetitions composed of four plants per experimental unit by treatment. The plots were constituted of 4 pruning times: April, May, June, and July of 2014 period; and the sub-plots were constituted of three intensities of fructification pruning, classified based on the distance from the soil base: short pruning at a plant height of 80 cm, medium pruning at 120 cm and long pruning at 180 cm (Figure 3). For each time, a line of 12 plants with homogeneous characteristics in age, height and crown diameter were selected. Before applying the treatments, the defoliation technique was employed (removal of all the leaves, fruits and flowers present) in all the plants in order to create uniformity in each productive stage. In the 2014 period, pruning was done in three heights. In the period 2015, only the plants with a height of 180 cm were pruned again. Plants which were pruned in the 2014 period, 80 and 120 cm high, were no longer pruned in the 2015 period, since they were not successful in the fructification process however they were left to continue with vegetative growth and so were continued to be evaluated to determine the time, in days, to reach the phenological phase of production.

Data collection

The experiment was evaluated during a time of 19 months which was divided into two periods: 1) April of 2014 until December of 2014 and 2) January of 2015 until October of 2015). The variables evaluated were: the number and length of shoots (NS and LS); the number of flowering buds (NFB); the number of small fruits (NSF) and the number of harvested fruits (NHF). Finally, the behavior of the different phenological stages in the camu-camu plants based on the different times and intensities of fructification pruning during the periods of evaluation, was analyzed. The following characteristics were also analyzed (in days): commencement of sprouting (CS), vegetative growth (VG), end of harvest (EH), flowering phase (FLP), fructification phase (FP), maturation of the fruit (MF), the start of harvest (SH) and end of harvest (EH) after fructification pruning.

Data analysis

The data was transformed and submitted to variance analysis and the treatment methods were statistically compared with Tukey's test at 5% probability ($P < 0.05$) utilizing the SISVAR statistical analysis program (Ferreira, 2010).

Results and discussion

The results show that camu-camu plants pruned to 180 cm in the month of April, bore fruit in October (after 6 months and 10 days approximately), likewise plants pruned in May bore fruit in November, just as the plants pruned in June bore fruit in November and plants pruned in the month of July bore fruit in December of 2014.

In the period of 2015, camu-camu plants that were pruned at 180 cm in January, bore fruit in July and the plants pruned in the month of February bore fruit in August. Likewise, the plants that were pruned in March bore fruit in September and finally the plants pruned in April, bore fruit in October. In this context the work had a duration of 19 months (from April 2014 to October 2015).

Period – 2014

Based on the summary of the variance analysis (Table 1) of the data obtained during April–July of 2014, an interaction was observed between the pruning time (PT) and pruning intensity (PI) factors for the shoot length (SL) and number of flowering buds variables (NFB). However, for the following variables: the number of shoots (NS); number of small fruits (NSF); and number of harvested fruits (NHF), only effects from the pruning intensity factor were observed (Table 1).

Number and length of shoots

In relation to the number of shoots variable (NS) in the period April–December of 2014 (Table 2), it is observed that the short, medium and long, or tip removal intensity, pruning did not present significant statistical differences in the four pruning times. However, upon comparing the pruning intensities it is observed that there are significant statistical differences among them. In this sense, the one that distinguished itself with the largest number of shoots was the long pruning (Figure 4). The values attained for the long pruning were 146, 145, 99 and 132 shoots, and 56, 58, 39 and 33 shoots for the short pruning in the months of April, May, June and July, respectively. These results show that the emission of sprouts was independent of the time of pruning.

The high emission of shoots in the plants with long pruning was a result of the minimum percentage of cutting, given that only the branches that were outside of the symmetrical structure of the crown were trimmed. Contrarily, when pruning is done at a lower level, a great number of secondary and tertiary branches were removed, causing a decrease in the emission of sprouts.

The results obtained in this study coincide with those of Serrano *et al.* (2008) on intensities of fructification pruning in the *Psidium guajava* L., where it was noted that independent

Table 3. Number of small fruits (NSF) and number of harvested fruits (NHF), based on the effect of the time and intensity of the pruning during the 2014 period. Values are means of four repetitions composed of four plants per treatment.

Pruning intensities	NSF				NHF			
	Pruning times							
	April	May	June	July	April	May	June	July
Short	0 Ab	0 Ab	0 Ab	0 Ab	0 Ab	0 Ab	0 Ab	0 Ab
Medium	0 Ab	0 Ab	0 Ab	0 Ab	0 Ab	0 Ab	0 Ab	0 Ab
Long	431.0 Aa	432.0 Aa	380.0 Aa	401.0 Aa	301.0 Aa	308.0 Aa	289.0 Aa	317.0 Aa
Average	333.3	167.7	52.0	134.3	166.7	74.0	32.7	111.7

For each pruning time (line), the mean values followed by at least one capital letter did not differ based on the Tukey's test ($P < 0.05$).
For each pruning intensity (column) the mean values followed with at least one common did not differ based on the Tukey's test ($P < 0.05$).

Table 4. Summary of the variance analysis of the number of flowering buds (NFB), number of small fruits (NSF) and number of harvested fruits (NHF) of camu-camu during the 2015 period.

Sources of variation	GL	Mean value squares		
		NFB	NSF	NHF
Block	3	18,341.85	13,414.13	10,796.25
Pruning time (PT)	3	68,697.07**	35,310.74*	23,472.43**
Residual 1	9	11,348.45	9,035.56	2,850.88
Intensity (I)	2	224,682.64**	223,680.44**	175,535.58**
PT × I	6	28,331.62^{ns}	33,903.55*	21,210.24*
Residual 2	24	14,935.4	11,535.14	5,033.61
CV (%) 1		60.32	86.27	70.21
CV (%) 2		69.20	97.47	93.30

* Significant at 5% level; **Significant at 1% level; ^{ns} not significant.

Table 5. Simple effects of the pruning time and its intensity on the number of flowering buds (NFB) of camu-camu plants during the 2015 period. Values are means of four repetitions composed of four plants per treatment.

Pruning times	NFB
April	106.0 c
May	440.0 b
June	480.0 b
July	880.0 a
Average	476.5
Intensities of pruning	
Short pruning	20.0 c
Medium pruning	173.0 b
Long pruning	896.0 a
Average	363.0

Values followed by at least one common letter did not differ based on the Tukey's test ($P < 0.05$).

of the pruning time, the plants subjected to long pruning presented larger numbers of shoots, while plants submitted to short pruning presented lower values. In the same way Amorim (1997) showed that when a larger number of pairs of leaves are left on the stems upon fructification pruning, there is a larger number of emitted and productive shoots, probably due to a larger number of buds and reserve substances. Likewise, Bañados (2015) signaled that a drastic pruning on *Vaccinium myrtillus* resulted in excessive vegetative growth and few fruits, causing an imbalance between the vegetative and productive portions of the plant.

For the length of shoots variable (LS-cm) in Table 2, it was observed that the plants with medium and short pruning, presented significant statistical differences in relation to the plants with long pruning in all months except in the month of June. The most noteworthy values are 67.7 and 58.0 cm in the month of April for the medium and short pruning, respectively, while the long pruning of plants presented values from 28 to 31 cm in the studied months (Figure 5). In relation to the length of the shoots, the results obtained in this study coincide with those reported by Silva *et al.* (2002) where a severe or excessive pruning done on a mango tree (*Mangifera indica* 'Tommy Atkins') such as cutting of thick stems of more than 2 inches in diameter generated abundant vegetative growth. In the same way Vázquez-Valdivia *et al.* (2009), working with different intensities of pruning in young mango trees (same cv. Tommy Atkins), observed that higher intensities of pruning at 100 cm in height produced more vigorous and longer lengths of shoots, than when pruning was done at higher heights.

Numbers of flowering buds, small fruits and harvested fruits

Regarding the variable for number of flowering buds (NFB) in Table 2 it was observed that the plants with long pruning were the only ones that emitted flowering buds, presenting significant statistical differences in comparison with the short and medium pruning, seeing that they did not emit flowering buds in this period (Figure 6). Likewise it is observed that in the months of April, May and July there

Table 6. Number of small fruits (NSF) and number of harvested fruits (NHF) of camu-camu as a result of the time and intensity of fructification pruning during the 2015 period. Values are means of four repetitions composed of four plants per treatment.

Pruning intensity	NSF				NHF			
	Pruning times							
	April	May	June	July	April	May	June	July
Short	5 Ac	13 Ac	8 Ac	8 Ac	2 Ab	0 Ac	2 Ac	3 Ac
Medium	14 Bb	71 Ab	100 Ab	144 Ab	8 Cb	26 Bb	16 Bb	73 Ab
Long	761 Ba	1,057 Aa	719 Ba	822 Ba	449 Ba	669 Aa	375 Ca	492 Ba
Average	260	330	276	325	153.00	231.66	131	189

For each pruning time (line), the mean values followed by at least one capital letter do not differ based on the Tukey's test ($P < 0.05$).
For each pruning intensity (column) the mean values followed with at least one common letter do not differ based on the Tukey's test ($P < 0.05$).

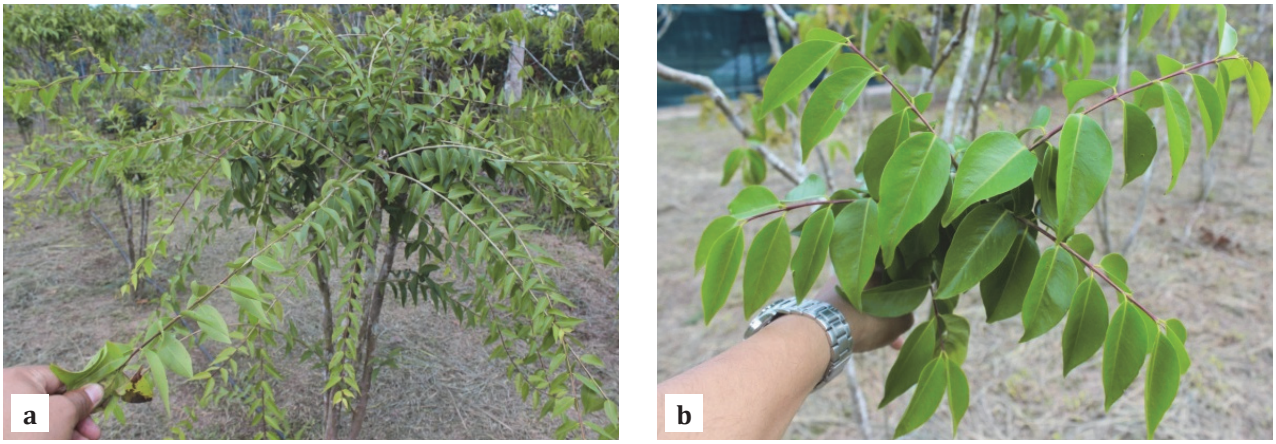

Figure 5. a) Longest length of shoots (pruning at a height of 80 cm), b) least length of shoots in camu-camu plants (pruning at a height of 180 cm) in the IIAP, Peru, June, 2014.

were no statistical differences among them, however, they demonstrated a significantly superior performance to the pruning done in the month of June (Table 3). In relation to the variable for the number of small fruits (NSF) and number of harvested fruits (NHF) in the 2014 period, the plants pruned at 180 cm from the soil base were the only ones that presented productive characteristics with averages of 411 small fruits and 304 harvested fruits (Figure 7).

As for the number of flowers, small fruits and fruits harvested variables, the results obtained concur with those of Vázquez-Valdivia and Barraza (2007), who mention that when trees are pruned in a severe manner, the production in the subsequent years is nil, and only as of the third year after pruning do they begin to emit the first flowering buds, then as of the fourth year, acceptable production is obtained. Equally Silva *et al*. (2002) verified that when a severe pruning was done in *Mangifera indica* trees the fruit yield diminished drastically because the vegetative and reproductive functions are antagonistic; they further mention that fructification is a consequence of the accumulation of carbohydrates, and that this is higher in new stems than in old and thick stems.

In the same way Kulkamp de Souza *et al*. (2014) working with the intensity of pruning in *Vaccinium myrtillus* plants, verified that during the first two years, light and moderate pruning presented better production per plant as opposed to severe pruning, demonstrating that the latter is not a viable option for this culture. Moreover Mathews *et al*. (2016), while working with different types of plantation and cropping management in camu-camu, found that pruning delayed fruit production.

Period – 2015

In the 2015 period, the NFB, NSF and NHF characteristics were evaluated in order to observe the behavior of the plants resulting from the types of pruning done. In the variance analysis for the pruning times it is observed that there is a significant interaction of the time and intensity of the pruning factors for the following two variables: number of small fruits (NSF) and number of fruits harvested (NHF). On the other hand, there were simple effects of the intensity and time of pruning on the number of flowering buds variable (NFB) (Table 4).

In relation to the number of flower buds variable (NFB), the most outstanding time was April with 880 FB, presenting significant statistical differences in relation to the other times. The long pruning at 180 cm from the soil base was the factor that presented the most significant results when compared to the short and medium pruning (Table 5; Figure 4).

In relation to the number of small fruits variable (NSF), the plants with long pruning at a height of 180 cm from the soil base, in the month of May, presented 1,057 small fruits on average. This is statistically superior to the pruning done at 80 cm (short pruning) and at 120 cm (medium pruning) from the soil base in the other months. Also it is observed that the plants pruned at lower heights began to emit flowering buds but in smaller quantities, most notably the medium pruning in May, June and July, with 71, 100 and 144 SF, respectively. As for the short pruning, all of the times and types of pruning behaved in a similar fashion with a value of 9 small fruits on average (Table 6).

Table 7. Times in days of the different phenological stages of camu-camu plant development following the different treatments (times and intensities) of fructification pruning during the period of evaluation: commencement of sprouting (CS), vegetative growth (VG), end of harvest (EH), flowering phase (FLP), fructification phase (FP), maturation of the fruit (MF), the start of harvest (SH) and end of harvest (EH) after pruning of fructification.

Pruning times	Intensity of fructification pruning																				
	Short pruning							Medium pruning							Long pruning						
	CS	VG	FLP	FP	MF	SH	EH	CS	VG	FLP	FP	MF	SH	EH	CS	VG	FLP	FP	MF	SH	EH
Short	13	225	510	535	595	612	638	11	240	410	501	551	573	585	16	90	110	121	180	195	210
Medium	11	210	510	535	595	608	635	9	210	405	493	543	563	590	9	88	120	135	176	190	214
Long	12	180	510	535	595	612	631	13	180	302	456	504	520	543	11	93	122	139	175	185	211
Long	18	185	510	535	595	614	628	17	150	402	451	500	520	540	13	96	126	140	178	197	215
Average	14	200	510	535	595	612	633	13	195	380	475	525	525	565	12	92	120	134	177	192	213

Figure 6. a) There are no flower buds in camu-camu plants pruned at a height of 80 cm; b) Presence of multiple flower buds in camu-camu plants pruned at a height of 180 cm; both in the first year of evaluation in the IIAP, Peru, August, 2014.

Figure 7. Reduced fruit yield in camu-camu plants pruned at a height of a) 80 cm compared to a height of b) 180 cm, in the IIAP, Peru, October, 2014.

With respect to the number of harvested fruits (NHF), the plants that were pruned at a height of 180 cm from the soil base in May presented 669 fruits harvested. The plants pruned at 80 cm (short pruning) and at 120 cm (medium pruning) presented minimum values of 0 and 8 fruits harvested, respectively (Table 6).

In the same way Larcher (2006) notes that the formation of flowers and fruits competes with vegetative growth, and in the case of loss of biomass, there is a removal of reserve substances, causing a reduction in the reproductive capacity of the plant. In this study, the short pruning was the one that caused the greatest removal of biomass. For this reason, the plants submitted to this type of pruning presented lower quantities of productive stems, and less harvested fruits per plant, which caused a decrease in production. These results concur with those of Paula de Santos (2009), which determined that the intensity of the short or drastic pruning caused delayed flowering and significantly reduced the productivity per area of *Morus nigra*.

Camu-camu plants, when improperly pruned, had a fruit yield negatively affected, because the plants entered a state of juvenility (Table 6). The reduced or zero fruit yield in camu-camu plants as a product of inadequate pruning would certainly affect farmers financially for an extended period. In that sense onwards, it is recommended to perform pruning fructification at the correct height, to not alter the production cycle.

Behavior of camu-camu plants at the different phenological stages based on time and intensity of fructification pruning

In relation to the short pruning, the commencement of sprouting (CS) occurred at 14 days after pruning. During a time frame of 200 days, the shoots were in the phase of vegetative growth (VG). The flowering phase (FLP) occurred at 510 days. The fructification phase (FP) began at 535 days, the maturation of the fruit (MF) occurred at 595 days, the start of harvest (SH) occurred as of 612 days and the end of harvest (EH) was at 633 days on average.

When medium pruning was done at a height of 120 cm from the soil base, the time for the initiation of the vegetative and reproductive phenological phases was similar to the time for the short pruning. The time for the productive cycle up to the end of the harvest was 565 days on average, which means that it took a time of more than 18 months. With respect to the long pruning done at 180 cm from the soil base, it took a total time to 213 days on average up until the end of harvest (EH), equivalent to 7 months, in the 2014 period as well as in the 2015 period (Table 7).

With regard to the vegetative characteristics of the camu-camu plants taken through the different intensities of pruning, it is observed that there are meaningful differences in relation to the time for initiation of each one of the vegetative and reproductive stages. In this sense, the reproductive cycle of the camu-camu plants, which were pruned at a height of 80 cm, began after 20 months but in insignificantly small quantities. Thus it may be said that the camu-camu plants pruned at these heights begin to emit flowers and fruits in the second year, but, in lesser quantities, resulting in economic loss for the agriculturalist by not having a harvest in the first year of pruning.

Contrarily to when the plants were pruned to 180 cm, the fructification characteristics were not affected in the first year. These results obtained coincided with Abanto *et al*. (2014b) and Abanto *et al*. (2011) when research was conducted on fructification pruning and fertigation in adult camu-camu plants. The authors noted that a crop cycle of the camu-camu took 206 and 205 days from pruning to harvest with agronomical management of fructification pruning and manual defoliation, and further standardized and diminished the productive cycle from one crop per year to two in 14 months. Similar results were obtained by Sánchez (2011) after the application of the fructification pruning and manual defoliation on adult camu-camu plants; harvest was achieved at 215, 203 and 206 days. The results obtained in this work will help the small, medium and large scale farmers utilize the best pruning height in camu-camu plants to obtain a sustainable production, because it introduces an innovation of simple and efficient agronomic management. Farmers will be able to learn about this innovation through technical assistance which can be delivered by engineers, technicians and field assistants through a field school methodology ("learning by doing"). This innovative management practice is meant to ensure camu-camu farmers to harvest fruit in quantity and quality every year. Proper pruning practices in camu-camu plants should benefit farmers in making them more productive and competitive, and also in allowing them to revalue their native products, increase prices and improve their income and living conditions.

Conclusion

Pruning camu-camu plants at a long height proved to make fructification in less time regardless the season it is performed. Long pruning on camu-camu plants stimulated the growth and development of fruitful branches, which allowed a yearly fruit production. Further experiments are ongoing to find out the best fertilization practices matching the pruning innovation and restoring or improving the soil fertility in sustainable camu-camu orchards.

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