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Yield and Fruit Quality of Loquat Trees as a Result of Flower Bud Thinning

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Abstract: The size and appearance of loquats are crucial for their acceptance in the consumer market. The loquat tree has intense fruiting, which suggests thinning flower buds in order to improve the quality of loquat fruit production. This study was performed in the Paraíba Valley region of the state of São Paulo, in the subtropical region of southeastern Brazil to assess intensities of flower thinning at full bloom on the yield and fruit quality of loquat trees. The study was carried out over two consecutive harvest seasons. Trees of the cultivar 'Precoce de Itaquera' were used in a randomized block design with five intensities of hand thinning of the flower buds (4, 6, 8, 10, and 12 buds per cluster), with seven replicates. For all treatments, the clusters were bagged as soon as they were thinned. After harvesting, the number of fruit sets, cluster and fruit mass, yield, longitudinal and transverse lengths, number and mass of seeds, soluble solids content, titratable acidity, ripeness index, and pH of the fruit pulp were assessed. An overall improvement was achieved by maintaining four flower buds per cluster. This intensity of thinning provides greater fruit setting on the cluster, as well as larger and sweeter fruit. The highest cluster weight and yield were obtained by maintaining 12 flower buds per cluster.

Keywords: *Eriobotrya japonica* (Thumb.) Lindl.; fruit setting; hand thinning; seeds

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1. Introduction

The loquat (*Eriobotrya japonica* (Thumb.) Lindl.), also known as Chinese plum, Japanese plum, or Japanese medlar, is a fruit tree from the Rosaceae family. Originally from China, it has adapted well to subtropical and temperate conditions, which has allowed it to spread to several countries around the world [1]. This fruit is grown mainly in China, Japan, Pakistan, India, Brazil, Mauritius, Madagascar, the United Kingdom, the United States, Australia and Mediterranean countries. Worldwide loquat production is approximately 549,220 tons on a cultivated area of 131,260 hectares [2]. Brazil stands out as the world's fifth largest loquat producer, with a production of 830 tons, harvested from 151 hectares in 2017 [3]. The state of São Paulo leads national production, especially the Alto Tietê region, which produces approximately 80 percent of the state's loquats [4].

The loquat is a hardy, perennial subtropical pome fruit that is harvested in relatively large terminal clusters, and blooms abundantly in well-acclimatized areas, making it an interesting crop for smallholders [1]. Despite its importance to the economy throughout the world and especially in the state of São Paulo, Brazil, there are few studies on the management of the loquat tree with the aim of improving the quality of the fruit for the fresh market [5].

The fruit of the loquat tree, which grows in panicles, is oval, round, and pear-shaped, 3 to 5 cm long, with yellow or orange skin and white, yellow, or orange flesh, depending on the cultivar [1]. Loquat is a fruit that stands out for its sweet and sour taste and high nutritional value. In addition to malic acid, sucrose, fructose, and a greater amount of tartaric acid, loquat is a source of minerals and vitamin C [6]. The fruit has a high concentration of pectin, which is favored in the manufacture of jams and jellies [7]. It also has a high content of phenolic compounds and antioxidant activity. These qualitative attributes make loquat a relevant choice for the consumption of bioactive compounds beneficial to human health [8,9]. The nutritional value of the fruit explains the growing interest in loquat, both for fresh consumption and for industrial uses.

The loquat is grown in 27 municipalities in the state of São Paulo and is considered a subtropical fruit tree of great importance to the region [10]. Among the main cultivars are 'Precoce de Itaquera' (also named Fukuhara), 'Mizuho', and 'Precoce de Campinas' (IAC 165-31) [11]. The Precoce de Itaquera (Fukuhara) cultivar is the most widely grown in the state of São Paulo and is also the oldest registered loquat cultivar in the region. In 1999, it was officially registered in the National Cultivar Register by the Campinas Agronomic Institute (National Cultivar Register, number 03306) [12]. In addition to early maturing, its main characteristics are high vigor and high tree production [13].

Under favorable soil and climate conditions, most loquat cultivars, especially 'Precoce de Itaquera' (Fukuhara), tend to have a high fruit set, which can result in a reduction in fruit size due to interference in the plant's source–drain relationship [14,15]. Therefore, in order to meet the needs of both growers and consumers, it is important to search for management practices that guarantee larger and better-quality fruit. As fruit size is critical for loquat marketing, thinning has become a mandatory practice [5,10,11,16]. The appearance and size of the fruit are fundamental to the commercialization of loquats on the fresh fruit market, making it necessary to thin and cover the fruit [2,17] during its development in the field in order to guarantee loquats with higher marketing standards [18].

Thinning flower buds is an essential practice in the management of the loquat tree, as it can have a direct impact on the productivity and quality of the fruit, factors that determine the value of the crop. By reducing competition between developing fruit, this technique makes it possible to obtain larger, more uniform fruit with better organoleptic characteristics, which are fundamental aspects for meeting the demands of the consumer market. In this way, the adoption of thinning can make a significant contribution to the sustainability of production and the profitability of orchards, benefiting loquat producers.

The production of larger and more valuable fruits is guaranteed at better market prices by hand fruit thinning [19]. Hand thinning of flowers or young fruits reduces competition, and increases the growth rate and size of remaining fruits, due to the greater balance in relation to the source [20]. Although hand thinning increases production costs because it requires trained labor [21], it is considered the most efficient thinning technique because it can efficiently control the number of thinned fruits when compared to mechanical or chemical thinning [14,22].

Hand or chemical thinning is generally carried out at the beginning of fruit development, when it is certain that the fruit set will be successful [21]. Hand thinning of young fruit in loquat has already been studied for other loquat cultivars. However, for the cultivar

Precoce de Itaquera (Fukuhara), studied in this experiment, there are still no reports on the subject. Previous studies indicate that, in order to increase the size of the loquat, it is suggested that the fruit be thinned out manually, keeping four to ten fruits per bunch, as proposed by Crane and Caldeira [23], which guarantees a 25 to 100 percent increase in fruit size. Grassi et al. [24] also observed gains in the size and weight of loquats by keeping four fruits per cluster. Retaining three to five young fruits per cluster resulted in a significant increase in fruit weight and the percentage of marketable fruit [24].

However, there is still a need for studies evaluating the hand thinning of loquat flower buds. This is because earlier flower thinning may allow for an even greater gain in balance in relation to source/sink, reducing competition for nutrients and energy between the reproductive and vegetative organs [25]. This early balance may allow the plant's resources to be directed more efficiently towards the development of the remaining fruit, resulting in improvements in the final quality of the loquat, as already observed in other fruit trees [26,27].

Flower bud thinning is a crop management technique that can improve productivity and fruit quality and, consequently, the profitability and sustainability of loquat orchards. Therefore, the aims of this study were to assess flower bud thinning effects on the yield and fruit quality of the cv. 'Precoce de Itaquera' loquat tree cultivated in subtropical conditions.

2. Materials and Methods

2.1. Plant Material and Experimental Area Description

The study was undertaken in Taubaté, São Paulo state, in southeastern Brazil, located at 23°01′49.61″ S and 45°30′28.25″ W, with an altitude of 565 m.a.s.l. The region has a Cfa climate, or subtropical climate with hot summers, according to the Köppen–Geiger classification system. The study region is characterized by rainy summers and dry winters, with an average annual rainfall of 1.335 mm [28], concentrated between December and February, and an average temperature of 21 °C [29,30]. The climate data for the two harvesting seasons were collected from the National Institute of Meteorology—INMET (Figure 1). The soil of the study site is classified as a Latossolo Vermelho Amarelo according to the Brazilian System of Soil Classification [31].

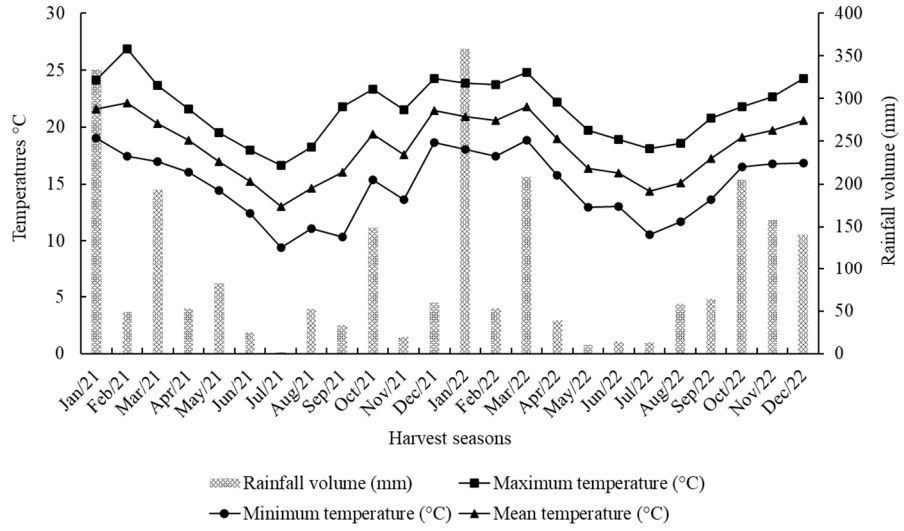


Figure 1. Climatic data for the two harvesting seasons of the 'Precoce de Itaquera' loquat at the experimental site.

Eight-year-old 'Precoce de Itaquera' (Fukuhara) loquat trees were used, grown at a spacing of 4 m apart in each row with 4 m between rows, totaling 625 trees per hectare. The

loquat trees originated from seedlings grafted onto the same cultivar and were grown in a cup shape, with 4 secondary branches. Weed control, fertilization and shoot removal were performed according to the recommended cultural practices [32]. Pruning was carried out in November, after the harvest, in the two harvest seasons evaluated using a kraft paper bag to prevent sunburn and russeting [24]. All the treatments were bagged on the same day as thinning, and this protection was maintained until the fruit ripened, corresponding to growth stage 807 on the Biologische Bundesanstalt, Bundessortenamt und Chemische Industrie (BBCH) scale [33].

The evaluations were carried out in two consecutive harvest seasons, the first in 2021 and the second in 2022.

2.2. Treatments and Experimental Design

Fruit thinning is a mandatory practice for crops, keeping four fruits per bunch. In this study, the treatments comprised the number of flower buds in each cluster on each tree (4, 6, 8, 10, and 12 flower buds) and the crop seasons evaluated. The control treatment was four flower buds per cluster, similar to the practice traditionally used by producers, i.e., retaining 4 fruit per cluster.

Thinning was carried out at the full-bloom stage, corresponding to the 605th growth stage of the BBCH scale, when at least 50% of flowers are open, with the first petals failing [33]. On each tree evaluated, the excess floral buds per cluster were thinned out across the canopy of the plants, keeping only the number corresponding to each treatment.

The experimental design employed a randomized block design in a double factorial scheme (5 flower bud thinning intensities $\times$ 2 harvest seasons), with seven blocks, one tree per experimental plot, and two guard trees outside for each treatment.

2.3. Harvest and Sample Preparation

The clusters were picked from the tree with pruning shears when they had reached the point of harvest (growth stage 807 on the BBCH scale) [33], i.e., when the fruit was completely yellow, in the month of October in both harvest seasons [33] and were assessed for physico-chemical characteristics in samples of fifty fruits per treatment.

The longitudinal and transverse lengths were measured with a digital caliper model USB/Absolute (Digimess, São Paulo, Brazil) and the values were expressed in millimeters. Fresh cluster, fruit, and seed masses were measured using an analytical scale model AG 200 (Gesaka, São Paulo, Brazil). The fruit set was expressed as a percentage (%) and obtained by dividing the number of flower buds initially retained in each treatment by the number of fruits harvested. Yield (t ha^{-1}) was estimated by the product of the number of fruit sets per treatment, the mass of fruit, and the number of trees per hectare. The number of seeds was obtained by directly counting the number of seeds in each fruit.

Soluble solids content was determined using a digital refractometer model Palette 101 (Atago, Tokyo, Japan) and expressed in °Brix. Titratable acidity and pH were measured using an automatic titrator model 848 Titrino Plus (Metrohm, Herisau, Switzerland) and results were expressed as a percentage of malic acid. Ripeness index or ratio was obtained by dividing the soluble solids content by the titratable acidity.

2.4. Statistical Analysis

The obtained data were subjected to analysis of variance (ANOVA) using R Studio software R 4.3.0 (R Core Team, 2023) [34]. Data on thinning intensity (4, 6, 8, 10, and 12 flower buds) were analyzed using polynomial regression ($p \leq 0.05$ and 0.01) when significant, and data on harvest seasons (2021 and 2022) were analyzed using Tukey's test for mean comparisons ($p \leq 0.05$). The data for the fruit set percentage were transformed to $\text{arcsen}\sqrt{x/100}$.

Pearson linear correlation was used to estimate the degree of association between the number of flower buds and the variables assessed. The responses were grouped using multivariate analysis with the aid of Statistical Analysis Software (SAS), version 8.2, using principal component analysis (PCA) to characterize the interactions between harvest seasons and thinning intensities.

3. Results

The results of the analysis of variance indicated a significant difference ($p < 0.05$) between the intensities of flower bud thinning and harvest seasons only for cluster mass, yield, and soluble solids content. The fruit set was significantly influenced ($p < 0.01$) only by the intensities of flower bud thinning. There was an effect of harvest seasons on the longitudinal lengths, fruit mass, number and mass of seeds, titratable acidity, pH, and ratio of the loquats (Table 1).

Table 1. F-values, coefficients of variation (CVs), and means for fruit set (FS), longitudinal length (LL), transverse length (TL), cluster mass (CM) and mass of fruit (FM), number (NS) and mass of seeds (MS), yield (YD), soluble solids (SS), titratable acidity (TA), pH, and ratio of the 'Precoce de Itaquera' (Fukuhara) loquat tree as a result of intensities of flower bud thinning and harvest seasons.

Sources of Variation	F-Values											
	FS	**LL**	**TL**	**CM**	**FM**	**NS**	**MS**	**YD**	**SS**	**TA**	**pH**	**Ratio**
I. thinning (IT)	4.04 **	1.45 ^{ns}	2.39 ^{ns}	27.49 **	1.84 ^{ns}	2.21 ^{ns}	0.98 ^{ns}	20.83 **	5.03 **	1.13 ^{ns}	1.31 ^{ns}	0.95 ^{ns}
Season (S)	1.40 ^{ns}	69.37 **	0.001 ^{ns}	255.03 **	38.76 **	37.44 **	13.59 **	41.65 **	1.60 ^{ns}	89.49 **	118.99 **	76.91 **
IT × S	1.16 ^{ns}	0.51 ^{ns}	0.001 ^{ns}	5.36 **	0.58 ^{ns}	1.48 ^{ns}	0.82 ^{ns}	8.35 **	3.70 *	1.21 ^{ns}	0.36 ^{ns}	1.05 ^{ns}
CV (%)	10.69	5.74	8.12	19.90	16.50	25.01	20.80	39.55	8.30	26.41	3.84	27.35
Thinning intensities	1st season											
	FS	LL	TL	CM	FM	NS	MS	YD	SS	TA	pH	Ratio
4	92.5 a	44.5 a	39.6 a	118.7 b	31.2 a	5.2 a	5.9 a	6.7c	12.8 a	3.7 a	4.8 a	3.6 a
6	83.3 a	46.0 a	42.4 a	165.1 b	32.0 a	4.5 a	6.2 a	7.8c	12.8 a	3.9 a	4.7 a	3.3 a
8	88.1 a	45.9 a	43.9 a	232.7 ab	35.9 a	6.0 a	7.7 a	13.1 b	12.2 a	4.1 a	4.6 a	3.0 a
10	84.5 a	45.7 a	41.4 a	264.8 ab	32.4 a	5.9 a	6.9 a	15.6 ab	12.6 a	3.9 a	4.7 a	3.3 a
12	81.2 a	43.7 a	40.6 a	341.3 a	31.9 a	5.9 a	7.0 a	17.8 a	12.1 a	4.4 a	4.6 a	2.8 a
MSD ($p < 0.05$)	16.4	5.1	6.1	147.4	11.5	2.1	2.3	3.5	1.5	1.3	0.3	1.5
SD	4.0	1.2	1.5	36.6	2.8	0.5	0.6	4.9	0.5	0.3	0.1	0.4
	2nd season											
4	87.5 a	50.4 a	39.6 a	291.8c	39.8 a	3.4 a	5.3 a	8.7c	14.2 a	3.2 a	4.8 a	4.6 a
6	88.3 a	51.8 a	42.3 a	521.8 b	47.8 a	3.4 a	5.4 a	14.8 b	11.8 b	3.0 a	4.6 a	4.3 a
8	88.8 a	54.1 a	43.9 a	725.8 a	48.3 a	3.4 a	5.4 a	22.9 a	11.1 b	3.6 a	4.7 a	3.3 a
10	80.0 ab	50.9 a	41.4 a	668.6 ab	40.8 a	2.9 a	5.2 a	20.7 a	11.0 b	3.3 a	4.7 a	3.5 a
12	70.0 b	51.3 a	40.6 a	747.9 a	42.3 a	4.8 a	5.8 a	22.1 a	12.2 b	3.9 a	4.6 a	3.1 a
MSD ($p < 0.05$)	16.4	5.1	6.1	147.4	11.5	2.1	2.3	3.5	1.5	1.3	0.3	1.5
SD	4.0	1.2	1.5	36.3	2.8	0.5	0.6	4.9	0.5	0.3	0.1	0.4

ns = not significant; * = significant at 5%; ** = significant at 1% by the F test. MSD: minimum significant difference. SD: standard deviation. Means followed by the same letter in the columns do not differ statistically according to the Tukey test ($p < 0.05$).

The percentage of fruit set decreased due to the higher number of flower buds per cluster (Figure 2). The lowest percentage of fruit set was observed in the treatment with the highest number of flowers per cluster at thinning, a result possibly associated with greater competition between sinks. Fruit set in the treatment with 4 flower buds per cluster was 15% higher than in the treatment with 12 flower buds per cluster.

Flower bud thinning intensities combined with harvest times affected the cluster mass (Figure 3A) and yield (Figure 3B) of 'Precoce de Itaquera' (Fukuhara) loquat, with higher averages for these characteristics as more flower buds were retained per cluster. The average cluster mass and yield for the first and second harvest seasons were 224.54 g and 591.22 g, and 12.23 t ha^{-1} and 17.84 t ha^{-1}, respectively (Table 2).

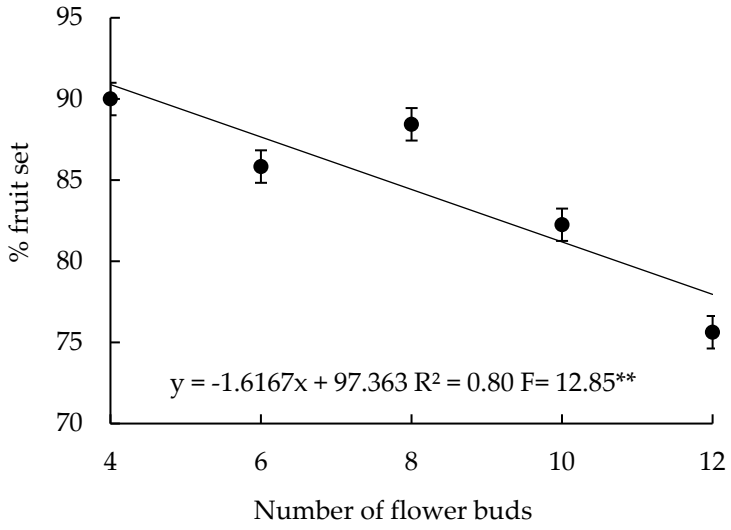


Figure 2. Fruit set percentage of the 'Precoce de Itaquera' (Fukuhara) loquat tree as a result of intensities of flower bud thinning. ** = significant at 1% by the F test.

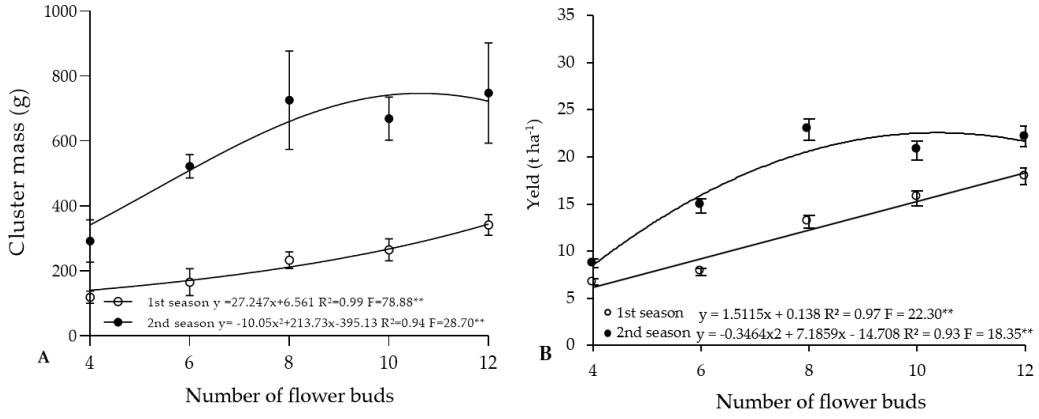


Figure 3. Cluster mass (g) (**A**) and yield (t ha^{-1}) (**B**) of 'Precoce de Itaquera' (Fukuhara) loquat as a result of flower bud thinning intensities and harvest seasons. ** = significant at 1% by the F test.

Table 2. Average cluster mass (g), yield (t ha^{-1}), fruit mass (g), longitudinal length (mm), number and mass of seeds (g), titratable acidity (% malic acid), ratio and pH of 'Precoce de Itaquera' (Fukuhara) loquats as a function of two harvest seasons assessed.

Harvest Seasons	CM	YD	FM	LL	NS	MS	TA	Ratio	pH
1st season	224.54 b	12.23 b	32.70 b	45.18 b	5.56 a	6.75 a	4.14 a	3.16 a	4.72 a
2nd season	591.22 a	17.84 a	43.81 a	51.73 a	3.58 b	5.43 b	3.52 b	6.40 b	4.19 b
MSD ($p < 0.05$)	46.57	3.75	3.62	1.59	0.66	0.73	0.47	0.75	0.09
p-value	0.0001	0.0001	0.0001	0.0001	0.0001	0.0007	0.001	0.0001	0.0001
SD	16.23	5.95	1.26	0.56	0.23	0.25	0.16	0.26	0.03

Letters followed by the same letter in the columns do not differ statistically by the Tukey test ($p \leq 0.05$). CM: cluster mass. YD: yield. FM: fruit mass. LL: longitudinal length. NS: number of seeds. MS: mass of seeds. TA: titratable acidity. MSD: minimum significant difference. SD: standard deviation.

It was observed that only harvesting seasons significantly affected fruit mass, longitudinal length, and number and mass of seeds (Table 2). These results suggest that the size of the loquat fruit depends on the climatic conditions of the growing regions each season.

The harvest seasons had an isolated effect, with the highest average mass and the largest longitudinal length found in the loquats harvested in the second season, with values

of 43.81 g and 51.73 mm, respectively. However, the opposite was observed for the mass and number of seeds, with the highest values in the first harvest (Table 2).

The soluble solids content only differed between treatments in the second harvest season, with a higher value when four flower buds were maintained per cluster (Figure 4). The average soluble solids content obtained in the second season for the treatment with four flower buds per cluster was higher than the other thinning intensities, with values that exceeded 14 °Brix (Figure 4). The ripeness index or ratio was higher in the second harvest (6.40) compared to the first harvest season (3.16). The titratable acidity and pH were higher in the fruit from the first harvest season, with an average of 4.14% and 4.72% malic acid, respectively (Table 2).

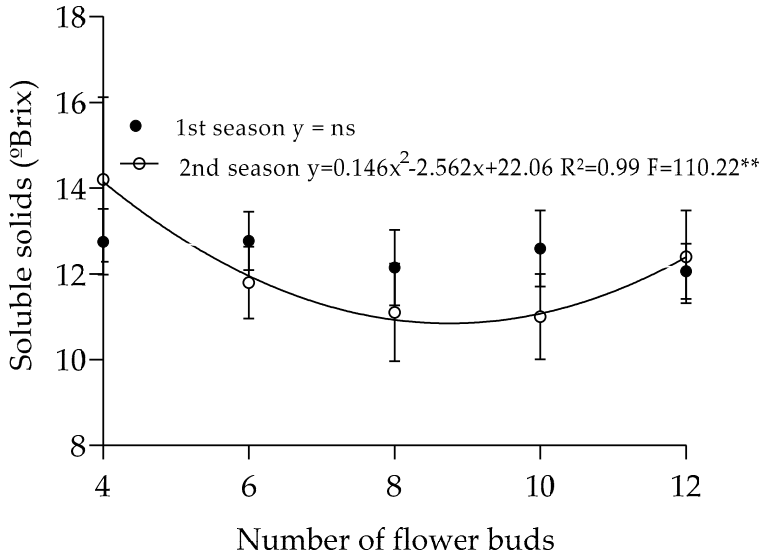


Figure 4. Soluble solids content of 'Precoce de Itaquera' (Fukuhara) loquat as a function of flower bud thinning intensities and two harvest seasons. ns = not significant; ** = significant at 1% by the F test.

Principal component analysis (PCA) indicated that all the physico-chemical variables of 'Precoce de Itaquera' (Fukuhara) loquats were influenced in the first harvest, highlighting that the permanence of four flower buds per cluster (T1-2021) leads to greater fruit set and seed development, as evidenced by the positive correlation between the aforementioned variables and the first principal component. The increases in the transverse length and mass of the loquats are positioned in opposition to the characteristics of the seeds and the physico-chemical characteristics of the fruit (Figure 5).

The correlation analysis between flower bud thinning intensities and physical and physico-chemical characteristics indicated that a greater number of flower buds per cluster results in an increase in cluster weight and the number of seeds per fruit, as shown by the positive correlation coefficients of 0.88 and 0.42, respectively (Table 3). In addition, the results suggest that maintaining a greater number of flower buds per cluster reduces the percentage of fruit set, soluble solids content, pH, and ratio, as indicated by the negative correlation coefficients of −0.60, −0.75, −0.47, and −0.48, respectively (Table 3).

Table 3. Pearson's linear correlation coefficients between thinning intensities the physico-chemical characteristics of 'Precoce de Itaquera' (Fukuhara) loquats across two harvest seasons.

	CM	FSP	FM	LL	TL	NS	SM	SS	TA	pH	Ratio
Number of flower buds	0.88	−0.60	−0.01	−0.04	0.04	0.42	0.29	−0.75	0.22	−0.47	−0.48

CM: cluster mass. FSP: fruit set percentage. FM: fruit mass. LL: longitudinal length. TL: transverse length. NS: number of seeds. SM: seed mass. SS: soluble solids. TA: titratable acidity.

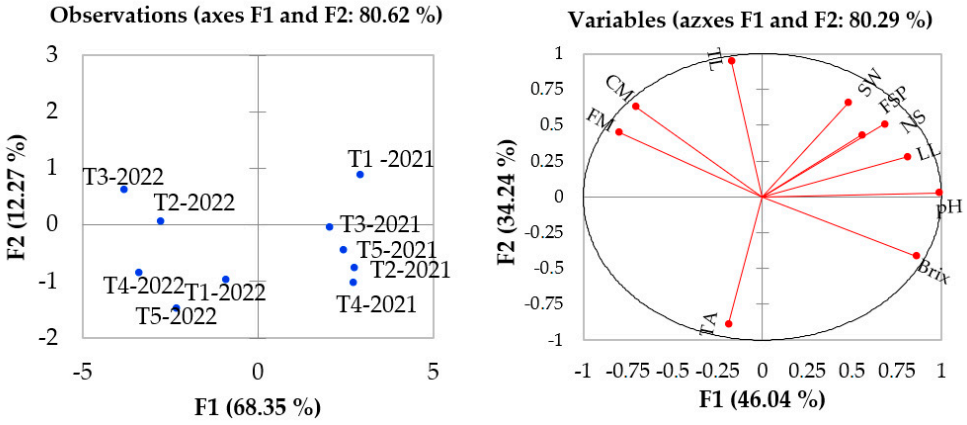


Figure 5. Principal component analysis (PCA) of 'Precoce de Itaquera' (Fukuhara) loquat as a function of flower bud thinning intensities and two harvest seasons. CM: cluster mass (g); TA: titratable acidity; SW: seed weight (g); NS: number of seeds; LL: longitudinal length (cm); TL: transverse length (cm); FSP: fruit set percentage; FM: fruit mass (g). T1: 4 flower buds; T2: 6 flower buds; T3: 8 flower buds; T4: 10 flower buds; T5: 12 flower buds.

4. Discussion

Hand or chemical thinning is generally carried out at the beginning of fruit development, when it is certain that the fruit set will be successful [21]. Although flower bud thinning is carried out earlier than fruit thinning and may allow trees to allocate fewer carbohydrate reserves, it is not certain that all the flowers retained at the time of this thinning will develop into loquats, even if the floral panicle is protected from the action of abiotic factors, as was the intention in this study. A study by Wu et al. [25] on the effect of flower and fruit thinning and fruit bagging on the growth and quality of the 'Changqi Zaosheng' loquat confirms the hypothesis of better results with flower bud thinning. The authors reported that flower thinning effectively reduced nutrition consumption and increased fruit set by 49.1%, compared to treatments with a greater number of flowers retained after thinning. In the present study, thinning intensity with four flower buds per cluster also resulted in a higher fruit set, being 15% higher than in the treatment with 12 flower buds, corroborating previous studies (Figure 2).

The loquat forms flowers in panicles and normally produces 10 to 15 fruits per cluster [8]. In this study, the results showed that cluster mass increased with an increase in the number of flower buds per cluster of loquat. Yields were also higher when more flower buds were retained per cluster. However, it is important to note that the commercial utilization rate of this fruit in supply and marketing centers takes into account the size of the fruit, which is more important than yield (t ha^{-1}) in determining the price of loquat. The caliber of loquat is one of the quality attributes used to determine the price in the fresh fruit market, that is, the larger the size of the fruit produced, the better the remuneration [4].

Studies with peach [35], litchi [36], date palm [37], pomegranate [38], and plum [39] revealed that the choice of flower thinning would result in an earlier balance of the plant's source–sink relationship, which could promote a greater reallocation of carbohydrates to the remaining fruit and, consequently, an improvement in the physical and chemical characteristics of the fruit. Oliveira et al. [35] concluded that, due to a better nutritional balance between the sink tissues from the beginning of the growth stage, there was an increase in the number of peach fruits over 60 mm in length.

The balance in the number of fruits per tree also contributes in the long term to mitigating the effects of alternate bearing, which is common in loquat and was observed in this study due to the large variation in yield between the harvest seasons studied (Figure 3B). Maintaining a constant yield, which can be made possible by thinning flowers and fruit,

allows for greater production stability in lychee fruit trees and better quality of the fruit harvested [39]. Alternation of flowering and, consequently, production is also a common problem in lychee and was investigated by Chen et al. [36], who observed that chemical thinning with ethefon (106 mg L^{-1}) during flower thinning of lychee 'Guiwei' can manage flower clustering and can be used to save labor and increase production [40].

Gariglio and Agustí [41] indicated that competition between fruits is the factor that has the greatest influence on loquat development. Ojima et al. [42] recommended that thinning of loquat should be carried out very intensively, as the best results were achieved when four fruits were maintained per cluster, a number that provides loquats with appropriate mass and overall yields. Stellfeldt and Cuevas [16] also concluded that four fruits per cluster is the best crop load for the 'Algerie' loquat and that the loquat is also a species that can cope well with water scarcity during fruit development.

Thinning also influences the mineral composition of loquat fruits, altering nutrient concentrations in both flesh and rind tissues [43]. However, increased thinning intensity has been associated with a higher incidence of purple spot disorder, possibly due to accelerated fruit development and increased sugar accumulation [43]. Chemical thinning using naphthalene acetic acid (NAA) has been explored as an alternative to hand thinning, with higher doses producing larger fruit sizes but lower overall yields [44,45].

In this study, the fruit had a higher pulp content in the first harvest season, a desirable characteristic for both fresh consumption and industrial processing, due to the lower fruit load per plant compared to the second. In loquat, thinning has led to an increase in fruit size, with some selections producing fruit weighing 50-60 g after thinning [46]. Farina et al. [47], evaluating the physico-chemical and sensory characteristics of the fruit of loquat cultivars in the Sicily/Italy region, reported a variation in fruit weight from 40 to 80 g.

The increase in fruit mass at the expense of the smaller number of fruits per cluster is closely related to the lesser competition between sinks, increasing the growth rate and the final size of the remaining fruits, due to the greater balance in the sink–source ratio of the trees [47,48]. It is worth noting that the size and mass of the fruit and seeds are important characteristics in terms of economic return and commercialization, as consumers are usually more willing to pay for larger fruit with smaller seeds [49]. Shah et al. [50] reported that a greater number and/or mass of seeds per fruit can increase the mass of the fruit, due to the greater amount of pulp. This is possibly due to the stimulation of cell division and growth by the hormones present in the seeds during fruit development [25].

Thinning is an indispensable practice for loquat trees when trying to produce high-quality fruit. A greater number of flower buds decreased the soluble solids content of the 'Precoce de Itaquera' (Fukuhara) loquat, suggesting that the hand thinning of flower buds could be used as a tool to improve the sweetness of the fruit. Sugars comprise the majority of soluble solids and can vary depending on the cultivar and production site [5]. The pH and ratio values were also negatively correlated with the higher number of flower buds per cluster. The ratio between sugars and acids is important for the flavor of the fruit, contributing to post-harvest quality and, consequently, the acceptance of the fruit by consumers [5,7].

However, several factors can interfere with the fruit's properties, such as the prevailing climatic conditions during the production cycle, the cultivar used, the intensity and timing of the thinning, as well as other cultural management practices. The variation in results between harvest seasons only adds to the effect of climate on the production and quality of loquat fruit.

In the current study, the climate data indicated a better thermal balance and also revealed more rainfall in the second season, between the months of August and October, the fruiting and harvesting season (Figure 1). As a result, in the second harvest mass,

the longitudinal length, soluble solids content, and ripeness index or ratio in the fruit were increased. The better fruit development in the treatment with a thinning intensity of four flower buds per cluster can be explained by the greater availability of nutrients and water, since there is less competition between the fruits due to their smaller quantity on the tree [24]. The most appropriate intensity of hand thinning in this study was obtained with four flower buds per cluster. As well as providing a greater fruit set in the cluster, the treatment with four flower buds provided larger and sweeter fruit, which can be better priced on the market. On the other hand, the treatment with 12 flower buds per cluster resulted in the highest cluster weight and yield, but with smaller fruit, which is not accepted by the consumer market. In general, depending on the season, this cultural practice increased fruit mass, longitudinal length, number and mass of seeds, soluble solids content, and ripeness index. In addition, other benefits can be achieved from these results, such as reducing harvesting costs, preventing branches from breaking due to the excessive number of fruits in the clusters, increasing the distribution of fruit with commercially acceptable lengths, balancing the crop load and, consequently, the profitability and sustainability of the loquat orchards in subtropical regions.

5. Conclusions

This study provided evidence that hand thinning applied at the full-bloom stage, with four flower buds per cluster of loquats, was the most appropriate intensity of thinning, which led to greater setting of the fruit in the cluster, larger fruit, and greater sweetness. The highest cluster weight and yield were obtained by maintaining 12 flower buds per cluster.

The findings obtained in this study highlight the need for further investigations to assess the effects of flower bud thinning on the physiology of the loquat tree due to the different climatic conditions during spring, the growth period, and fruit ripening. Ongoing evaluations must be carried out in order to be able to safely recommend the hand thinning of the flower buds of the 'Precoce de Itaquera' (Fukuhara) loquat, considering that this will contribute to better management of the production of fruit for natural consumption. For future studies, an economic analysis of the labor costs of thinning flower buds and fruit is recommended to assess the economic viability of these management practices in loquat orchards.

Further studies to substantiate the statements about the source/sink balance by assessing the carbohydrate content, as well as determining the qualitative properties and nutritional value of the fruit, such as the percentage of juice, vitamin content, and bioactive compounds, would improve the recommendations for using flower and fruit thinning in the loquat tree.

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