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STRAWBERRY CULTIVARS FRUIT PRODUCTION AND POSTHARVEST FROM TWO TYPES OF SAPLINGS

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ABSTRACT - The establishment of strawberry crops in southern Brazil is conditioned on the delivery of bare-root saplings imported from Argentina and/or Chile. An alternative to reduce dependence on the acquisition of these saplings is their replacement by clod-rooted saplings that form a clod. However, information on the agronomic performance of clod-rooted saplings is scarce. The aim of this work was to investigate whether the association between types of saplings and strawberry cultivars alters fruit production and postharvest. The research was carried out at the Horticulture Sector of the University of Passo Fundo, Passo Fundo, Rio Grande do Sul, Brazil, from March to December 2020, in a greenhouse. The plant material for the research consisted of saplings with bare-roots and saplings rooted in clods. The treatments were three cultivars ('Fronteras', 'Monterey' and 'Portola') and two types of saplings (bare-root and rooted in a clod), arranged in a randomized block design, with three replications and ten plants per plot. The productive potential and chemical quality of fruits were evaluated. Plants from saplings rooted in clods showed higher number and fruit production. Plants from bare -root saplings produced larger fruits. The postharvest of fruits was not altered by the treatments. The productive potential and postharvest of fruits of strawberry cultivars are not associated with the different types of saplings studied. Regardless of the cultivar used, plants from saplings rooted in clods have greater productive potential compared to plants from bare-root saplings. The fruits of the three cultivars tested in this study, from saplings with bare-roots or rooted in clods, present a balanced relationship between sugar and acidity, which makes the strawberries suitable for consumption.
Keywords: *Fragaria* x *ananassa* Duch., bare-root saplings, clod-rooted saplings.

PRODUÇÃO E PÓS-COLHEITA DE FRUTOS DE CULTIVARES DE MORANGUEIRO ORIUNDAS DE DOIS TIPOS DE MUDAS

RESUMO - O estabelecimento de lavouras de morangueiro no sul do Brasil é condicionado à entrega de mudas de raiz nua importadas da Argentina e/ou do Chile. Uma alternativa para reduzir a dependência da aquisição dessas mudas é sua substituição por mudas enraizadas que formam torrão. Porém as informações sobre o desempenho agronômico de mudas enraizadas são escassas. O objetivo do trabalho foi investigar se a associação entre tipos de mudas e cultivares de morangueiro altera a produção e pós-colheita de frutos. A pesquisa foi desenvolvida no Setor de Horticultura da Universidade de Passo Fundo, Passo Fundo, Rio Grande do Sul, Brasil, de março a dezembro de 2020, em ambiente protegido. O material vegetal da pesquisa foi constituído por mudas de raiz nua e por mudas enraizadas em torrão. Os tratamentos foram três cultivares (Fronteras, Monterey e Portola) e dois tipos de mudas (raiz nua e enraizada em torrão), dispostos no delineamento em blocos casualizados, contendo três repetições e dez plantas por parcela. Avaliou-se o potencial produtivo e a qualidade química de frutos. Plantas oriundas de mudas enraizadas em torrão apresentaram maior número e produção de frutos. Plantas provenientes de mudas de raiz nua produziram frutos maiores. A pós-colheita de frutos não foi alterada pelos tratamentos. O potencial produtivo e pós-colheita de frutos de cultivares de morangueiro não estão associados aos diferentes tipos de mudas estudadas. Independente da cultivar utilizada, plantas oriundas de mudas enraizadas em torrões apresentam maior potencial produtivo em relação às plantas oriundas de mudas de raiz nua. Os frutos das três cultivares testadas neste estudo, provenientes de mudas com raízes nuas ou enraizadas em torrões, apresentam uma relação equilibrada entre açúcar e acidez, o que torna os morangos aptos para o consumo.
Palavras-chave: *Fragaria* x *ananassa* Duch., raiz nua, muda enraizada.

INTRODUCTION

Rich in biomolecules with health-promoting activities, such as anthocyanins (CHIOMENTO et al., 2021a), strawberries (*Fragaria* x *ananassa* Duch.) have attracted the attention of consumers and producers worldwide. As it represents an important source of income for small and medium farmers, the cultivation of this vegetable in Brazil covers an area of 4,500 ha (ANTUNES et al., 2020), occupying the first position in the ranking of small fruit cultivation (CHIOMENTO et al., 2021b).

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The establishment of strawberry crops is linked to the quality and quantity of the acquired saplings (ANTUNES; PERES, 2013), prioritizing planting at the right time so that the crop can express its maximum productive potential (RAHMAN et al., 2014). In the Brazilian subtropics, most of these crops are implanted with imported bare-root saplings, developed mainly in Argentine and Chilean Patagonia (CHIOMENTO et al., 2020).

The harvesting point of saplings in Chilean Patagonia corresponds to the number of cold hours that the plant accumulates, which varies from 80 to 200 h, depending on the cultivar. Thus, the harvesting of saplings and their subsequent shipment to Brazil occurs seasonally. In addition, as the saplings are imported, there are often delays with their release by the Ministry of Agriculture, Livestock and Supply (MAPA) of Brazil. These facts hinder the availability of saplings at the indicated time for planting (early autumn), conditioning the transplant to the delivery of the saplings and this can compromise fruit production (COSTA et al., 2021).

An alternative to reduce the problems related to the use of bare-root saplings is its replacement for rooted saplings that form clods. However, information on the agronomic performance of clod-rooted saplings is scarce. Currently, the classification of strawberry cultivars in relation to their flowering divides plants into three groups: short-day (SD), neutral-day (ND) cultivars and summer plants (UC DAVIS, 2021). Regardless of the type of sapling acquired by producers, as strawberry cultivars used in the southern hemisphere, they are generally classified as ND and summer plants (CHIOMENTO et al., 2020).

The main costs inherent to the strawberry production system are infrastructure, labor and the purchase of saplings. Thus, the crop establishment phase is an important stage of the cultivation system due to its high relative value in strawberry production costs and the time the plants are exposed to adverse factors, from transplanting to the beginning of fruiting (TRENTIN et al., 2021). Therefore, research linked to the productive potential and postharvest of fruits of strawberry cultivars from different types of saplings will allow strawberry growers to choose materials adapted to subtropical cultivation conditions, with greater production and fruit quality. In addition, the results obtained will be able to expand the acquisition of saplings, enabling their transplantation at different times. Thus, the strawberry growers will be able to stagger the planting, the beginning of the harvest and the distribution of labor. In this way, these producers will not be dependent on bare-root saplings delivered at one time of the year.

The study hypothesis is that strawberry saplings rooted in clods, of ND cultivars, have greater productive potential. Therefore, the objective of this work was to investigate whether the association between types of saplings and strawberry cultivars alters the production and postharvest of fruits.

MATERIAL AND METHODS

The plant material for the research, supplied by the company Bioagro Comercial Agropecuária Ltda., consisted of saplings with bare-roots and saplings rooted in clods. The bare-root saplings came from the nursery of Agricola Llahuén, located in the region of Los Angeles, in Chilean Patagonia (33º 50' 15.41" S, 70º 40' 03.06" W). To obtain the saplings rooted in clods, also from the nursery at Agricola Llahuén, saplings from a commercial nursery were stored in a cold chamber, cleaned and planted in trays filled with commercial substrate.

The research was carried out at the Horticulture Sector of the University of Passo Fundo, Passo Fundo (28º 15' 41" S; 52º 24' 45" W), Rio Grande do Sul (RS), Brazil, from March (autumn) to December (summer) 2020, in a greenhouse measuring 510 m^2, with a semicircular roof, installed in the northwest-southeast direction. The galvanized steel frame is covered with a low-density polyethylene film with an anti-ultraviolet additive and a thickness of 150 µ.

The treatments studied, delineated in a bifactorial scheme, were three strawberry cultivars ('Fronteras', 'Monterey' and 'Portola') and two types of saplings (bare-root and rooted in a clod). The experiment was designed in randomized blocks, with three replications and ten plants per plot. Regarding flowering, 'Fronteras' cultivar is classified as SD, 'Monterey' cultivar as ND, and 'Portola' cultivar is classified as a summer plant.

Prior to the establishment of the experiment, soil samples were taken to obtain its chemical characterization. Ten subsamples of soil were randomly collected inside the greenhouse. The distance between subsamples was 5 m. Sampling was carried out with the aid of a cutting blade at a depth of 10 cm. All subsamples were placed in a container and homogenized. Then, approximately 500 g of soil was used for chemical analysis (Table 1).

TABLE 1 - Chemical properties of cultivated soil.

Clay	pH[1]	SMP	P	K	OM	Al	Ca	Mg	H+Al	CEC	Saturation		
											Bases	Al	K
(%)	(H_2O)	index	(mg dm^{-3})		(%)	---------- $cmol_c$ dm^{-3} ----------					---------- % ----------		
39	6.3	6.5	61.4	314	4.0	0.0	7.5	3.9	1.2	14.3	90	0.0	4.4

Sulfur	Boron	Manganese	Zinc	Copper
---------- mg dm^{-3} ----------				
6.2	0.2	4.5	11.1	1.1

[1]pH (H_2O): hydrogen potential in water; SMP index: Shoemaker-Mac'Lean-Pratt index; P: phosphorus; K: potassium; OM: organic matter; Al: aluminum; Ca: calcium; Mg: magnesium; H+Al: potential acidity; CEC: cation exchange capacity.

The strawberry planting system used was the conventional one (planting in the ground), in beds covered with mulching (thickness of 30 µ) and with dimensions of 15 m long x 1.0 m wide. Saplings rooted in clods were transplanted in March 2020 and bare-root saplings were transplanted in May (autumn) of the same year. The plants were distributed in a 0.30 x 0.30 m spacing scheme, with two rows of plants per bed.

The irrigation used in the experiment was located, using drip tapes, with a flow of 1.2 L h^{-1} per unit. The soil moisture content was monitored by tensiometers at a depth of 20 cm, with irrigation being activated when the content was less than -20 kPa. According to the chemical analysis of the soil (Table 1), liming was not necessary. Fertilization was carried out based on soil analysis. Nitrogen, phosphorus and potassium were applied with urea, monoammonium phosphate and potassium nitrate, respectively (CQFS – RS/SC, 2016). During the execution of the experiment, through a mini meteorological station, the air temperature (minimum, average and maximum) inside the greenhouse was monitored (Figure 1). Attributes related to fruit production and quality were evaluated.

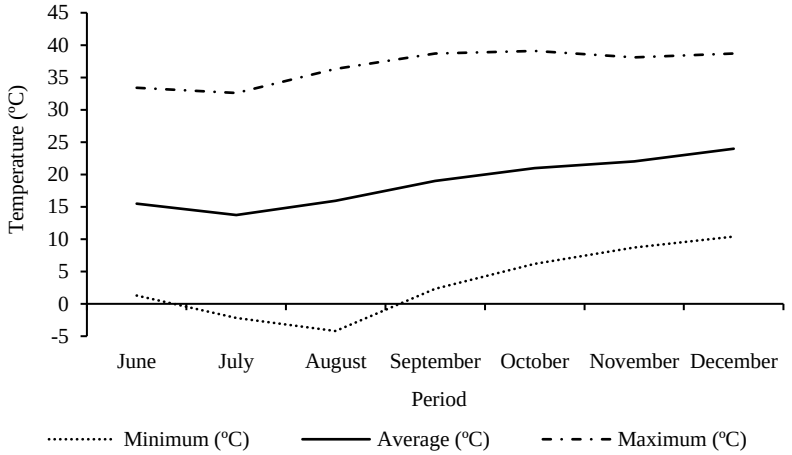

FIGURE 1 - Monthly minimum, average and maximum temperatures inside the greenhouse during the experiment.

From the fruiting, which occurred in June (winter) of 2020 in plants from saplings rooted in clods and August (winter) of 2020 in plants from bare-root saplings, the total number of fruits per plant (TFN, number) and the total fruit production per plant (TP, grams per plant), harvested when fully ripe, were evaluated per plant. The fruits were weighed in an electronic digital scale. In addition, the average fresh mass of fruits (AFFM, grams) was determined by dividing TP and TFN. Harvests took place until December 2020.

The fruit quality analysis was carried out at the peak of production, in November (spring) of 2020. The fruits chemical characteristics related to the content of soluble solids (SS), expressed in ºBrix, and total acidity (TA) were evaluated, expressed in % of citric acid, from 20 fruits of each treatment for each repetition. The TSS content was determined in an analog refractometer, while the TA was performed according to the norms of the Adolfo Lutz Institute (ZENEBON et al., 2008). To evaluate the flavor of the fruits, the SS/TA ratio was determined. The data obtained were subjected to analysis of variance (ANOVA) and, when there was significance, the means of treatments were compared using the Tukey test, at 5% probability of error, using the Costat® program.

RESULTS AND DISCUSSION

There was a significant effect only of the types of saplings regarding the three attributes of fruit production (Table 2). Plants from saplings rooted in clods presented higher TFN and TP by 38% and 32%, respectively, compared to plants from bare-root saplings (Table 3). However, plants from bare-rooted saplings produced fruits with an average fresh mass 8% higher than plants from saplings rooted in clods (Table 3).

On a global scale, annually, more than 300 million strawberry saplings are needed to establish commercial crops. Thus, the supply of different types of saplings, especially those with high vigor and physiological and phytosanitary quality, is a necessary improvement to meet the demands of strawberry growers (FAGHERAZZI et al., 2021). In Brazil, saplings correspond to the main investment in the implementation of the strawberry crop and are considered the starting point for the success of the crop and the producer (OLIVEIRA; SCIVITTARO, 2006). The prerequisites for successful cultivation establishment are, in addition to high vigor and physiological and phytosanitary quality of the saplings, the ability to promote a high survival rate and vegetative growth after transplanting (COCCO et al., 2016).

The quality of the acquired saplings is related to the productivity and quality of the produced fruits, being the starting point for obtaining a better response to the technologies used in the production process (OLIVEIRA; SCIVITTARO, 2006). The establishment of crops with saplings rooted in clods makes it possible to reduce the use of fumigant products for soil disinfestation and to obtain homogeneous saplings with a high survival rate after transplanting. This allows achieving greater precocity and fruit yield compared to saplings with bare-roots (GIMÉNEZ et al., 2008), which was verified in this study. Although other studies report that clod-rooted saplings can be an

alternative to reduce dependence on the purchase of imported saplings and to obtain early production in several producing regions (COCCO et al., 2011), many producers consider the productive potential of imported bare-root saplings larger, different from what was observed in this research.

TABLE 2 - Summary of the analysis of variance for the fruit production of strawberry cultivars and sapling types.

Causes of variation	Mean square			
	DF[1]	TNF	TP (g per plant)	AFFM (g)
Blocks	2	8.60^{ns}	640.34^{ns}	1.60^{ns}
Cultivars	2	63.16^{ns}	7262.41^{ns}	0.38^{ns}
Sapling types	1	506.68**	54364.67*	5.89*
Interaction	2	120.00^{ns}	18956.03^{ns}	0.07^{ns}
Residual	10	44.57	7160.14	0.70
TOTAL	17			
Mean		22.38	288.12	13.04
CV(%)[2]		15.83	19.36	6.42

[1]DF: degrees of freedom, TNF: total number of fruits, TP: total production; AFFM: average fresh fruit mass, [2]CV: coefficient of variation, *significant at the 5% probability level ($0.01 \leq p < 0.05$), **significant at the 1% probability level ($p < 0.01$), ^{ns}not significant ($p \geq 0.05$).

TABLE 3 - Strawberry production according to the types of saplings used.

Sapling types	TNF[1] (number per plant)	TP (g per plant)	AFFM (g)
Clod-rooted	27.68 a*	343.07 a	12.46 b
Bare-root	17.07 b	233.16 b	13.61 a
Mean	22.38	288.12	13.04
CV (%)[2]	29.83	29.36	6.42

*Means followed by the same letter in the column do not differ by the Tukey test ($p \leq 0.05$), [1]TNF: total number of fruits; TP: total production; AFFM: average fresh fruit mass, [2]CV: coefficient of variation.

In this study, no significant difference was found regarding the postharvest of strawberries produced by plants of different cultivars and different types of saplings (Table 4). Strawberry is demanded both for fresh consumption and for industrial processing. This fruit is an important food, being rich in fructose and sucrose, but it is low in carbohydrates (SANHUEZA et al., 2005). One of the parameters used as an indicator of fruit quality is the SS content. The main sugars present in fruits are glucose, sucrose and fructose (CHITARRA; CHITARRA, 2005). As the fruit matures, sugar content increases due to the transformation of starch into simple sugars (glucose and fructose) (GIARDI et al., 2002).

TABLE 4 - Summary of analysis of variance for fruit quality of strawberry cultivars and sapling types.

Causes of variation	Mean square			
	DF[1]	SS (ºBrix)	TA (%)	SS/TA
Blocks	2	0.45^{ns}	0.008^{ns}	3.43^{ns}
Cultivars	2	1.61^{ns}	0.009^{ns}	0.75^{ns}
Sapling types	1	0.16^{ns}	0.017^{ns}	1.87^{ns}
Interaction	2	1.52^{ns}	0.012^{ns}	0.58^{ns}
Residual	10	1.90	0.008	3.92
TOTAL	17			
Mean		7.73	0.80	9.66
CV (%)[2]		17.85	11.36	10.49

[1]DF: degrees of freedom; SS: soluble solids; TA: total acidity; SS/TA: flavor of the fruits, [2]CV: coefficient of variation, ^{ns}not significant ($p \geq 0.05$).

The sour or acidic flavor of the fruit is determined by the TA. During the fruit ripening period, the organic acid content decreases due to oxidation in the tricarboxylic acid cycle as a result of respiration. Thus, the acidity decreases due to maturation, so that the acidity variation can be an indication of the fruit's maturation stage (OLIVEIRA et al., 2005). The relationship between SS content and TA is the most important attribute with regard to the palatability of fruits, so this relationship gives the fruits a better balance between sweet and sour and thus generates a more pleasant and attractive flavor (KROLOW; SCHWENGBER, 2007). The values of this relationship considered ideal are between 8.5 and 14 (OSC, 2006). In this study, the mean value obtained for the SS/TA ratio was 9.66, indicating that the

fruits produced, regardless of the cultivars and type of sapling, were suitable for consumption.

Other studies must be carried out to adapt the production system of saplings rooted in clods to the needs of other producing regions, in order to enhance the strawberry production chain in Brazil.

CONCLUSIONS

The productive potential and postharvest of fruits of strawberry cultivars are not associated with the different types of saplings studied.

Regardless of the cultivar used ('Fronteras', 'Monterey' and 'Portola'), plants from saplings rooted in clods have greater productive potential compared to plants from bare-root saplings.

The fruits of the three cultivars tested in this study, from saplings with bare-roots or rooted in clods, present a balanced relationship between sugar and acidity, which makes the strawberries suitable for consumption.

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