

Original Research Article

PERFORMANCE OF STRAWBERRY VARIETIES UNDER GREENHOUSE FOLLOWING THREE CROPPING PRACTICES

ABSTRACT

Strawberry is a crop of high added value, which was extended to new producing zones such as the State of Mato Grosso in Brazil. Therefore, the need to test the adaptability of varieties to soil and climatic conditions arises. The study objective was to evaluate agromorphological traits, fruit yield and quality of strawberry to be cultivated under greenhouse conditions following three different cropping practices. Experiment design was a split-plot in four replications with three cropping practices as main plots and three strawberry varieties as subplots. Water application was made following a drip irrigation system. It came out that cropping practices did not influence strawberry fruit yield and quality. However, lower growth performance of strawberry was recorded on Ceramic Block compared to that of Vase and Slab cropping practices. Regardless of the cropping practice, San Andreas and Albion varieties were more productive with better quality fruit and adapted to local environment conditions than Oso Grande variety.

Keywords: agromorphological trait, fruit yield, fruit quality, hydroponic condition, commercial substrate, drip irrigation.

1. INTRODUCTION

Strawberry (*Fragaria ananassa*) is a species of great economic importance and of high added value in the horticultural sector at both national and international levels [1]. It is involved in

the diversification of agricultural systems, since it is widely cultivated in almost all regions of the world, including Brazil, with greater adaptability in mild climate regions.

The flavor (aroma and taste) and the intense red coloration of the fruits are determinants of consumer acceptance. The fruits have aromatic compounds that act on the nerves of smell and taste, thereby increasing appetite. The fruit has health benefits, facilitates digestion and improves liver function by its high natural sugars content. Thus, it is essential to identify varieties of strawberry most adapted to local environmental conditions and produce better quality fruits.

South America produces 318,686 tons of strawberry over just 11,000 hectares. Brazil, Argentina and Chile are the largest producers. In Brazil, the cultivated area is approximately 4,000 hectares, with an estimated annual production of 105,000 tons. The State of Minas Gerais is the largest national producer with approximately 40,000 tons per year, followed by São Paulo (29,000 tons per year). Rio Grande do Sul, Santa Catarina, Paraná, Espírito Santo and Rio de Janeiro, account for the remaining Brazilian strawberry producing zones [2].

The average yield of strawberry in Brazil is 30 Mg ha⁻¹ which reaches up to 60 Mg ha⁻¹ in areas of best farming practices. São Paulo is the high yielding state with 34 Mg ha⁻¹, followed by Rio Grande do Sul with 32 Mg ha⁻¹ and Minas Gerais with 25 Mg ha⁻¹ [2]

Strawberry producing zones in Brazil increase together with the use of best performing cultivars under tropical conditions with dry winter, well defined rainy season and temperatures above 25°C like the one prevailing in southern region of Mato Grosso.

The objective of the study was to evaluate the performance of three strawberry varieties cultivated under greenhouse following three different cropping practices.

2. MATERIALS AND METHODS

The experiment was conducted at the Federal University of Mato Grosso, University Campus of Rondonópolis, in a greenhouse located at latitude 16°27'50.8 "S and longitude 54°34'49.9" W at 230 meters altitude. Climate of the region is classified as Aw type with dry winter. The greenhouse used has a metallic structure with a covering polyethylene film and was equipped with an adiabatic cooling system. Experimental design was a split plot in four replications with three cropping practices as main plots (Plastic Vessel, Slab and Ceramic Block) and three strawberry varieties as subplots (San Andreas, Albion and Oso Grande). Net cropped area per plot was composed of 4 central strawberry plants per variety (Fig. 1).

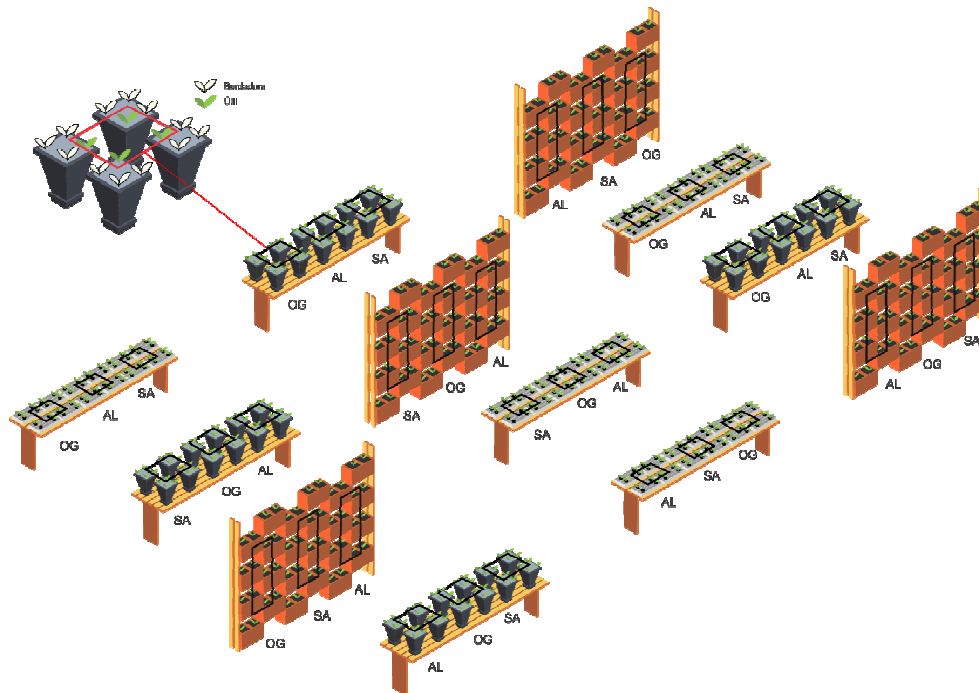


Fig. 1. View of the experimental design used.

For the plastic Vase system, wooden benches with dimensions of 2.40 m in length, 0.70 m in width and 0.85 m in height were installed. Twelve pots of 8 dm³ per plot were used, and 4 plants per pot were transplanted with a total of 48 plants.

In the Slab system, plastic bags measuring 0.40 m long, 0.35 m wide with a volume of 8 dm³, were placed on benches with the same design of the Vase system. At the top of each Slab, holes were drilled to transplant 4 plants, making 48 plants per plot.

On the other hand, for the constitution of the Ceramic Block system, hydraulic ceramic blocks were used in the civil construction area with dimensions of 0.19 m in height; 0.29 m long and 0.14 m wide. For the composition of the plots 24 blocks were used, alternately overlapped forming a wall of 1.52 m in height and 1.74 m in length, the ends being supported by screws fixed in wooden supports to provide support. The bottoms of the blocks were closed with mortar and for each block, two containers were formed with a volume of 2 dm³, totaling 4 dm³ per block. One plant was transplanted for each volume totaling 48 plants per block.

In all systems, holes were drilled for the drainage of water from the semi-hydroponic irrigation system.

For substrate formation, soil and commercial substrate were mixed. The soil used, classified as Oxisol [3], was collected in a Cerrado area near the Campus of Rondonópolis of the Federal University of Mato Grosso, in the 0.0 to 0.20 m deep layer. It was later sieved in a mesh of 2 mm for chemical and granulometric analyses and for correction, so as to increase the saturation of bases to 80% (Table 1).

Table 1. Chemical and granulometric analyses of Oxisol.

pH	P	K	Ca + Mg	Ca	Mg	Al	H	O.M.	Sand	Silt	Clay
-----H ₂ O-----	---mg dm ⁻³ ---		-----cmol _c dm ⁻³ -----					--g dm ⁻³ --	-----g kg ⁻¹ -----		
4.8	1.4	23	0.6	0.4	0.2	0.8	5.4	10.7	423	133	444

O. M. - Organic Matter

The commercial substrate TECHNOMAX®, recommended for the production of strawberries in semi-hydroponics, was used. It has in its composition organic materials, such as expanded vermiculite, peel of Pinus and Eucalyptus, coconut fiber and recovered paper fiber. Soil and substrate were homogenized in a ratio of 1:1 and mixed in a concrete mixer. After mixing, samples were collected for chemical analysis and subsequent fertilization recommendation (Table 2).

Table 2. Chemical and granulometric analyses of the substrate mixed with soil.

pH	P	K	Ca + Mg	Ca	Mg	Al	H	O.M.	Sand	Silt	Clay
-----H ₂ O-----	--mg dm ⁻³ --		-----cmol _c dm ⁻³ -----					--g dm ⁻³ --	-----g kg ⁻¹ -----		
6.1	35.4	189.6	5.39	3.9	1.49	0.0	6.53	52.6	456	134	410

O. M. - Organic Matter

The varieties used (San Andreas, Albion and Oso Grande) were recommended by Francisco Antônio Passos, a strawberry agronomist from the Brazilian Agronomic Institute of Campinas (IAC). The varieties have the following characteristics: San Andreas and Albion are of neutral days, developed by the University of California in 2008 and 2004, respectively. They have high content of soluble solids and total acidity, with large fruits, of appropriate shape and good flavor [4]. The Oso Grande variety was also developed by the University of California in 1977. A rather short but vigorous vegetation variety with high adaptation and production capacity [5].

The seedlings were purchased from the nursery of Baptistella Brothers, Campinas - SP. For acclimatization of the strawberry seedlings before transplanting to the cropping systems, 200 seedlings of each variety were separated. Afterwards, 600 plastic bags were prepared with 0.2

kg of substrate, with one seed per bag hand-irrigated. On April 12, 2016 the seedlings were transplanted to the three cropping systems.

A light reflecting polypropylene screen with 50% shading was opened on the cropping systems. The opening and closing of the screen occurred between 9:00 a.m. to 4:00 p.m., where the highest temperature of the day is recorded.

The irrigation system consisted of a 1 m³ carton, a single-phase centrifugal motor pump Model: ECSB-50M, Polyvinyl chloride tubes (PVC) measuring 32 mm in diameter for the main line and 16 mm polyethylene hoses as secondary lines for each experimental plot. Each line was elevated from the ground to the top of the benches, extending along it, where they were drilled for the installation of the Naan self-compensating drippers with average flow of 4 L h⁻¹. After installation of drippers, Naan brand cross connectors of 4 outlets of 5 x 4 mm and 4 micro-tubes of 5 mm were placed, which were fixed individually to the side of each plant with the aid of dripping piles (Fig. 2).



Fig. 2. View of central line of irrigation system and secondary lines

Irrigation was performed daily and the system was kept connected until the beginning of the drainage in the experimental plots. The nutrient solution used was formulated according to recommendation for strawberry [6].

The number of fruits and flowers, leaf area, number of commercial fruits, diameter of commercial fruits, commercial fruit mass, total soluble solids content (°Brix) and Total Titratable Acidity were evaluated.

At 30, 60 and 90 days after transplanting (DAT) the number of leaves and the number of flowers were evaluated. All the composite leaves and all the flowers present in the plants were counted. Leaf area was determined by means of a destructive method (at 90 DAT), in which leaves were removed from plants. After being cut, leaves and petioles were separated and later scanned using LI 3100 (LI-COR®) equipment.

Selection of commercial fruits was performed based on fruit diameter using a digital caliper. Fruits with a diameter greater than 15 mm and without deformations were considered commercial fruits [7]. For the number of commercial fruits, all fruits regarding each subplot were counted and weighed using a semi-analytical balance.

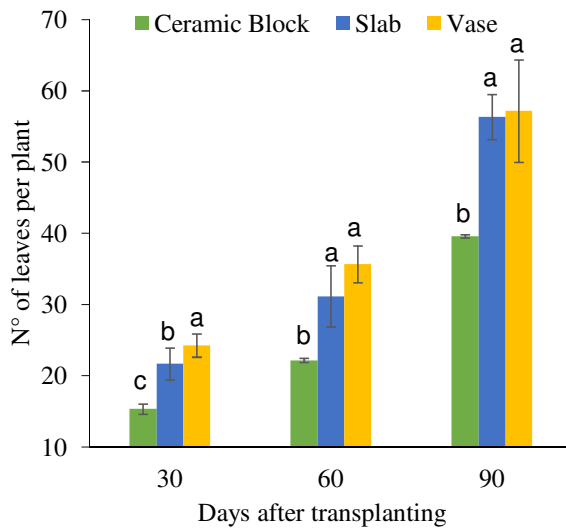
Fruit quality expressed in Brix i.e. total soluble solids content (TSS), was measured by means of a refractometer, obtaining the values in °Brix (IAL, 2005). To evaluate the Total Titratable Acidity (TTA) 5-10 g of homogenized pulp were used in presence of 100 ml of distilled water, 3 drops of phenolphthalein solution and 0.1 M of sodium hydroxide solution [8].

The data were submitted for ANOVA and Tukey test when F was significant ($P = .05$). All statistical analyses were performed using the SISVAR software [9].

3. RESULTS AND DISCUSSION

148 Cultivation systems and varieties did not present significant interaction, thereby providing
149 isolated responses. No significant difference was observed for soluble solids content and fruit
150 diameter. The cultivation systems did not influence the evaluated characteristics, except for
151 the number of leaves and leaf area. Regarding the varieties, San Andreas and Albion stood out
152 in relation to Oso Grande in all evaluations, except for the number of leaves.
153 The Vase and Slab culture systems differed statistically from the Ceramic Block in the 30, 60
154 and 90 DAT evaluations for the number of leaves (Fig. 3). At 30 DAT, the San Andreas and
155 Oso Grande varieties presented the highest number of leaves, followed by Albion, although
156 this did not differ statistically from the Oso Grande variety (Fig. 4). Regardless of the system,
157 there is a greater response of the San Andreas culture in relation to the others regarding leaf
158 production. This may be due to the greater robustness and adaptability of the variety in
159 relation to the edaphoclimatic characteristics compared to the others.

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161

162 **Fig. 3. Number of leaves per plant with different cropping practices 30, 60 and 90 DAT.**

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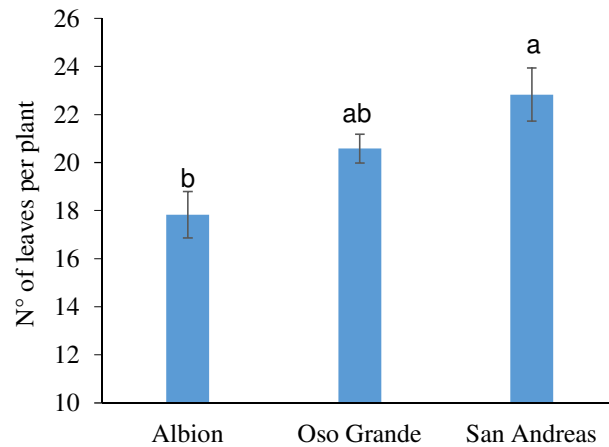


Fig. 4. Number of leaves per plant in strawberry varieties at 30 DAT.

Regarding flower production, there was a significant difference for the varieties only at 30 DAT. San Andreas and Albion did not differ statistically significantly from each other, whereas Oso Grande did not differ from Albion and had the lowest number of flowers (Fig. 5).

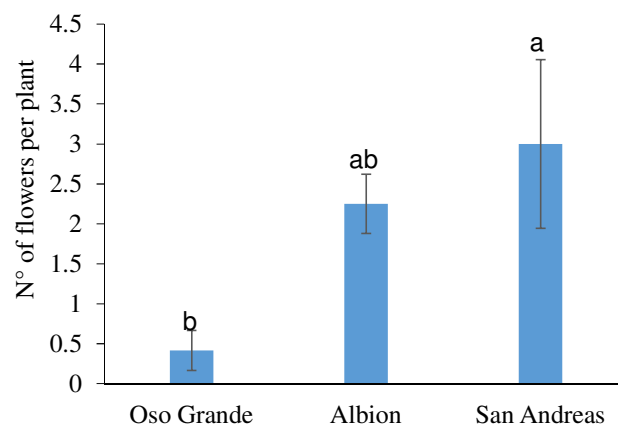


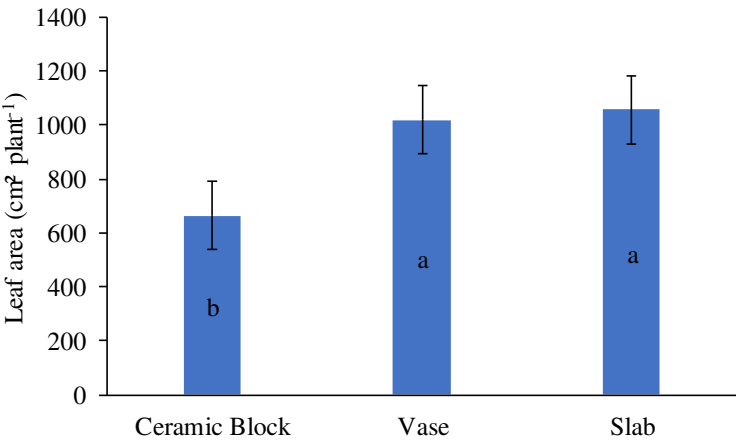
Fig. 5. Number of flowers per plant in strawberry varieties at 30 DAT.

175 | ~~Analyzing the number of leaves and flowers, we observed~~ Aa greater vegetative development
176 | of strawberry ~~was observed~~ regardless of cropping practices and ~~strawberry~~ cultivars. This
177 | may be an adaptive response of cultivars to weather conditions, such as elevated temperature
178 | (Table 3). The average temperature from May to August remained above 27°C. High
179 | temperatures provide greater vegetative development to the detriment of fruiting [10],
180 | although this characteristic is required in seedling production.

182 | **Table 3. Temperature and relative humidity recorded over strawberry growing period.**

Month	Climatic conditions	
	Mean Temperature (°C)	Relative Humidity (%)
May	29.56	94.63
June	27.67	95.04
July	27.37	76.27
August	27.12	93.74

183 |
184 | Leaf area of strawberry regarding Vase and Slab cropping practices was significantly high
185 | compared to that of Ceramic Block (Fig. 6).



186 |
187 | **Fig. 6. Average leaf area per strawberry plant following cropping practices used.**

Average leaf area was positively correlated with the number of leaves produced. Thus, the ~~greater-higher~~ the leaf production, ~~correlates with~~, the greater ~~is~~ leaf area. As previously observed, the Vessels and Slab systems provided the largest number of leaves and ~~consequently therefore~~, a larger leaf area, ~~which also reflected in the Ceramic Block system with number of leaves.~~

The lower performance of the Ceramic Block system may be related to the lower incidence of radiation on the strawberry, since the blocks are overlapping, causing shading in the plants of the lower blocks. Regarding commercial fruit production (NFC), the difference ~~observed~~ was ~~isolated-important~~ for ~~cultivars~~ San Andreas and Albion ~~cultivars~~ with higher fruit yield followed by Oso Grande with the lowest ~~production yields~~. The ~~dynamics-trend is similar that of are like the~~ previous variables, ~~since-as~~ the ~~strawberry~~ varieties ~~developed-showed~~ better ~~growth overin~~ the vegetative period ~~with better fruit yield and qualityare more likely to produce higher quantity and better quality of fruits.~~

~~The low~~Lower -fruit yield of ~~the~~ Oso Grande variety was probably due to ~~its~~ poor adaptation to ~~local the~~ climatic conditions ~~of the region. Thus, strawberry~~ Strawberry varieties of shorter ~~daylights susceptibility~~ -probably ~~were not adapted~~ ~~do not adapt~~ to ~~the~~ climatic conditions of ~~the~~ southern ~~region of~~ Mato Grosso (Fig. 7).

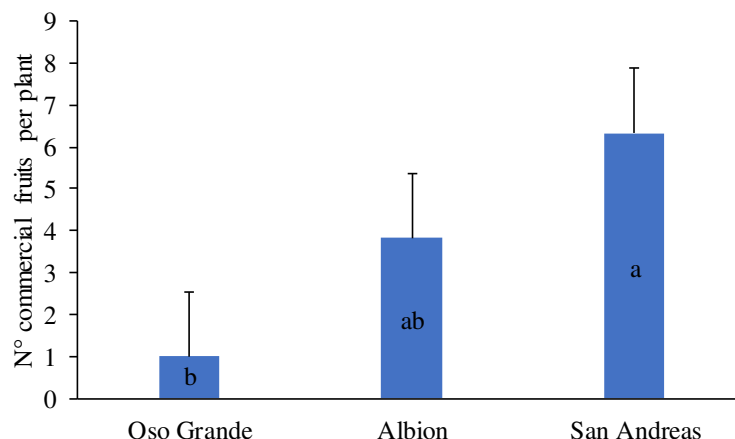


Fig. 7. Number of commercial fruits of three strawberry cultivars in semi-hydroponic cultivations.

The lower fruit yields were due to the less emission of flowers, possibly as a result of due to the higher elevated temperatures recorded (average of 27.93°C on average) during over the cultivation growing period, providing greater better crop vegetative development (stolon productions). The temperature significantly influenced strawberry growth and yields as reported by Chabot the development and production of the strawberry [11] and Stewart et al [1]. In general, flowering used to be enhanced favored by mild temperatures, while elevated higher temperatures promote induce higher better vegetative development [11]. Researchers Reduction in flowering and fruit yield was observed a reduction of flowers and fruits with an and an accelerated important increase in the emission of stolons, and high yields of deformed and small fruits due to the increase in of the local air temperature in the region during the day [12]. Strawberry fruit yields of strawberry fruits under greenhouse conditions are certainly linked related to the number of cold hours prevailing at that the seedling stage s receive in the greenhouses [13]. Some research works carried out under In study of the productive behavior

of neutral day cultivars in temperate climate in Pelotas-RS, showed that San Andreas variety produced an average of 11.216 fruits per plant on average [14].

The absence of pollinating insects, such as native bees, may also have affected the low production of commercial fruit yields as, since the greenhouse used was not equipped with adequate system that could enhance bees allows pollination by bees. Although better strawberry fruit yields and yield quality are very much influenced by certain species of bees. Pollination, either by distinct species of bees, provides higher production and quality of strawberry fruits [15].

In relation to the production of far as total fresh fruit mass is concerned, the San Andreas and Albion varieties showed better performance as opposed to that of Oso Grande, which reflects the lower flowering ability production mentioned previously.

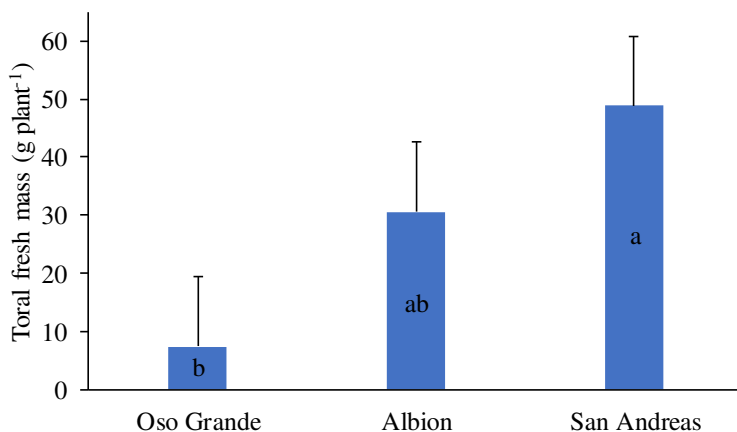


Fig. 8. Total fresh mass of commercial fruits regarding three strawberry of the Oso Grande, Albion and San Andreas varieties in semi-hydroponic cropping systems.

Some research works have shown high the superior performance of the San Andreas variety in relation compared to the other varieties under in conventional fertilization and

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organic ~~systems~~substrates, with a production of 20.96 g ~~infor the~~ dry fruit mass [16]. These results ~~showed demonstrate~~ the adaptability of ~~thate~~ variety ~~in relation to~~ site specific traits. ~~the characteristics intrinsic to the site. The~~ Albion variety ~~is also a has good adaptwell-~~ ~~adaptedability~~ and ~~high-yielding material with a performance of 342 g of fruit/plant in Passo Fundo-RS when grown on aproductivity. When evaluated in combinations of substrates, it produced on average 342 g plant⁻¹ in Passo Fundo~~ RS [17].

~~San Andreas and Albion varieties presented higher acidity than that of Oso Grande (Fig. 9). The varieties presented significance for Total Titratable Acidity, in which San Andreas and Albion presented higher acidity than Oso Grande (Fig. 9). The acidity is indicative of fruit quality, since the fruits have a lower sour taste at the time of harvesting, they will be more accepted by the consumers. The higher citric acid content of the cultivars both San Andreas and Albion varieties is does not seem to be not depreciative because not only, since they areit is responsible for the aroma of the_fruits but also, and, after harvesting, the soluble solids contents and acidity decrease as they , because these compounds are used with substrate for respiration [18] [19] [20].~~

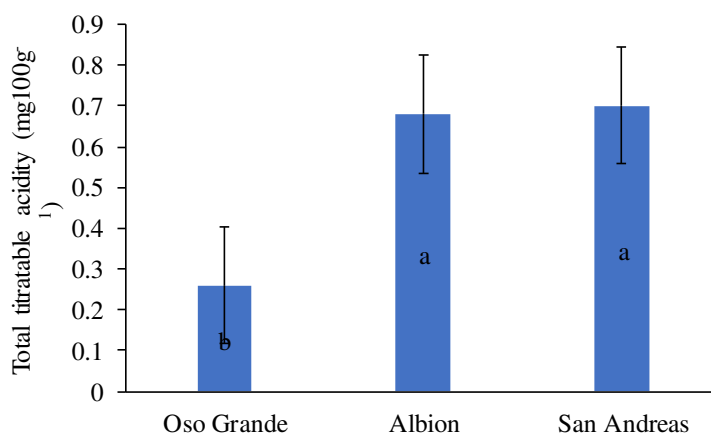


Fig. 9. Total Titratable Acidity of commercial fruits of three strawberry varieties in under semi-hydroponic crop systems.

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~~In relation to fruit acidity of, the~~ San Andreas and Albion varieties fits within ~~the an~~ acceptable range (0.73 - 1.58 %) [21], ~~which~~ showing that despite ~~the low~~ their lower yields production, the ~~fruits produced~~ yield quality is good quality. ~~For the Oso Grande cultivar T,~~ the total titratable acidity regarding the Oso Grande cultivar did not meet the standards values for the cultivar, possibly because ~~due of to the~~ its low adaptability to local climatic conditions of the variety to climate of the region. Fruit quality measured on that variety Researchers in the region of was higher than that determined in Minas Gerais region, by evaluating sensorial and chemical characteristics of strawberry fruits, observed values of acidity of (-0.65%) for the variety [22].

4. CONCLUSIONS

It came out that cropping practices did not influence strawberry fruit yield and quality. However, lower growth performance of strawberry was recorded on Ceramic Block compared to that of Vase and Slab cropping practices. Regardless of the cropping practice, San Andreas and Albion varieties were more productive with better quality fruit and adapted to local environment conditions than Oso Grande variety.

COMPETING INTERESTS

Authors declared that no competing interests exist.

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