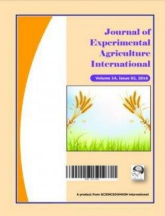

Journal of Experimental Agriculture International

19(3): 1-9, 2017; Article no.JEAI.38027
ISSN: 2457-0591
(Past name: American Journal of Experimental Agriculture, Past ISSN: 2231-0606)

Performance of Strawberry Varieties under Greenhouse Following Three Cropping Practices

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Authors' contributions

This work was carried out in collaboration between all authors. Authors TJAS, EMBS and HAWC designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors WF and TFD managed the analyses of the study. Authors WF and HAWC managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JEAI/2017/38027
Editor(s):
(1) Crepin Bi Guime Pene, Professor, Director of Research & Development, SUCAFCI-SOMDIAA, Ivory Coast.
(2) Dalong Guo, Professor, College of Forestry, Henan University of Science and Technology, Luoyang, People's Republic of China.
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(1) Ade Onanuga, Lethbridge College, Canada.
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(3) Jayath P. Kirthisinghe, University of Peradeniya, Sri Lanka.
Complete Peer review History: http://www.sciencedomain.org/review-history/22483

Original Research Article

Received 7th November 2017
Accepted 21st December 2017
Published 28th December 2017

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

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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 16º27'50.8" S and longitude 54º34'49.9" 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).

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 dm^3 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 dm^3, 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 dm^3, totaling 4 dm^3 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).

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).

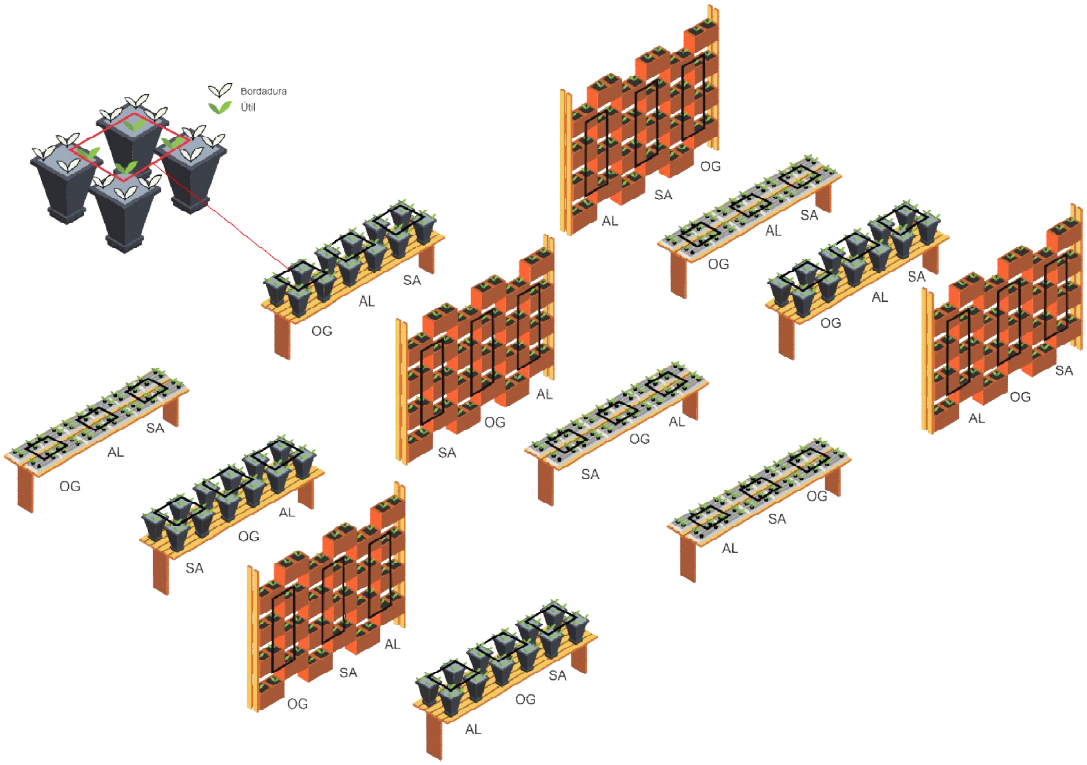

Fig. 1. View of the experimental design used

Table 1. Chemical and granulometric analyses of Oxisol

pH	P	K	Ca + Mg	Ca	Mg	Al	H	O.M.	Sand	Silt	Clay
------H_2O-----	---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

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_2O-----	--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 m^3 carton, a single-phase centrifugal motor pump Model: ECSB-50 M, 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).

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.

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

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

Cultivation systems and varieties did not present significant interaction, thereby providing isolated responses. No significant difference was observed for soluble solids content and fruit diameter. The cultivation systems did not influence the evaluated characteristics, except for the number of leaves and leaf area. Regarding the varieties, San Andreas and Albion stood out in relation to Oso Grande in all evaluations, except for the number of leaves.

The Vase and Slab culture systems differed statistically from the Ceramic Block in the 30, 60 and 90 DAT evaluations for the number of leaves (Fig. 3). At 30 DAT, the San Andreas and Oso Grande varieties presented the highest number of leaves, followed by Albion, although this did not differ statistically from the Oso Grande variety (Fig. 4). Regardless of the system, there is a greater response of the San Andreas culture in relation to the others regarding leaf production. This may be due to the greater robustness and adaptability of the variety in relation to the edaphoclimatic characteristics compared to the others.

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

A greater vegetative development of strawberry was observed regardless of cropping practices and cultivars. This may be an adaptive response of cultivars to weather conditions, such as elevated temperature (Table 3). The average temperature from May to August remained above 27°C. High temperatures provide greater vegetative development to the detriment of fruiting [10], although this characteristic is required in seedling production.

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

	Meteorological conditions	
Month	**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

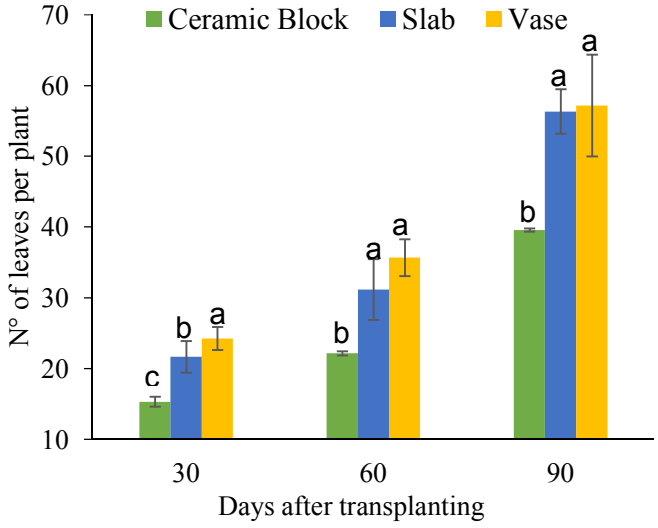

Fig. 3. Number of leaves per plant with different cropping practices 30, 60 and 90 DAT

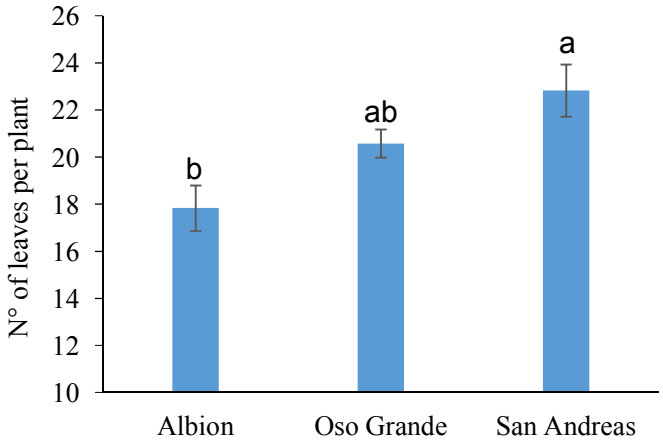

Fig. 4. Number of leaves per plant in strawberry varieties 30 DAT

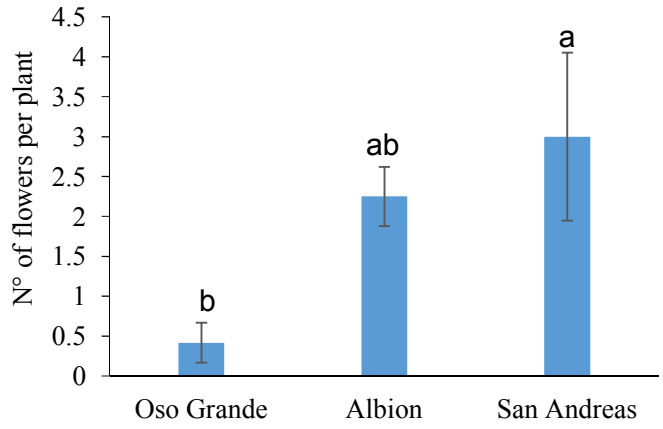

Fig. 5. Number of flowers per plant in strawberry varieties 30 DAT

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

Average leaf area was positively correlated with the number of leaves produced. Thus, the higher the leaf production, the greater is leaf area. As previously observed, the Vessels and Slab systems provided the largest number of leaves and therefore a larger leaf area. 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 important for San Andreas and Albion cultivars with higher fruit yield followed by Oso Grande with the lowest yields. The trend is similar that of previous variables, as the strawberry varieties showed better growth over the vegetative period with better fruit yield and quality. Lower fruit yield of Oso Grande variety was probably due to its poor adaptation to local climatic conditions. Strawberry varieties of shorter daylight susceptibility probably were not adapted to climatic conditions of southern Mato Grosso (Fig. 7).

Lower fruit yields were due to less emission of flowers, possibly as a result of higher temperatures recorded (27.93°C on average) over the growing period, providing better crop vegetative development. Temperature significantly influenced strawberry growth and yields as reported by Chabot [11] and Stewart et al. [1]. Flowering used to be enhanced by mild temperatures, while higher temperatures induce better vegetative development [11]. Reduction in flowering and fruit yield was observed with an

important increase in emission of stolons, high yields of deformed small fruits due to increase in local air temperature during the day [12].

Strawberry fruit yields under greenhouse conditions are certainly related to the number of cold hours prevailing at the seedling stage [13]. Some research works carried out under temperate climate in Pelotas-RS, showed that San Andreas variety produced 11.2 fruits per plant on average [14].

The absence of pollinating insects, such as native bees, may also have affected commercial fruit yields as the greenhouse used was not equipped with adequate system that could enhanced bees pollination. Although better strawberry fruit yields and yield quality are very much influenced by certain species of bees [15].

As far as total fresh fruit mass is concerned, San Andreas and Albion varieties showed better performance as opposed to that of Oso Grande (Fig. 8), which is related the lower flowering ability mentioned previously.

Some research works showed high performance of San Andreas variety compared to other varieties under conventional fertilization and organic substrates, with a production of 20.96 g in dry fruit mass [16]. These results showed the adaptability of that variety to site specific traits. Albion variety is also a well-adapted and high-yielding material with a performance of 342 g of fruit/plant in Passo Fundo-RS when grown on a combination of substrates RS [17].

San Andreas and Albion varieties presented higher acidity than that of Oso Grande (Fig. 9).

The higher citric acid content of both varieties does not seem to be depreciative because not only it is responsible for the aroma of fruits but also, after harvest, the soluble solid content and acidity decrease as they are used with substrate for respiration [18] [19] [20].

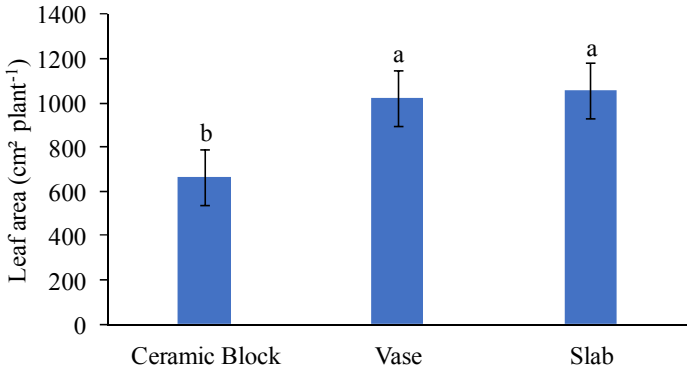

Fig. 6. Average leaf area per strawberry plant following cropping practices used

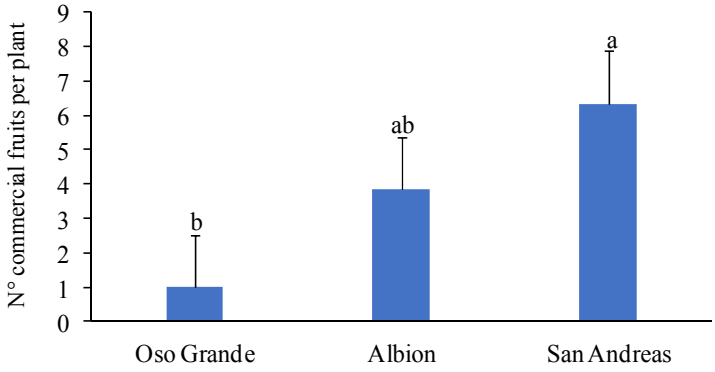

Fig. 7. Number of commercial fruits of three strawberry cultivars in semi-hydroponic cultivations

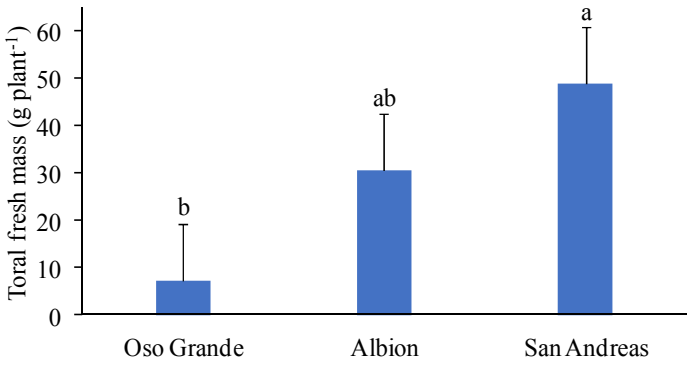

Fig. 8. Total fresh mass of commercial fruits regarding three strawberry varieties in semi-hydroponic cropping systems.

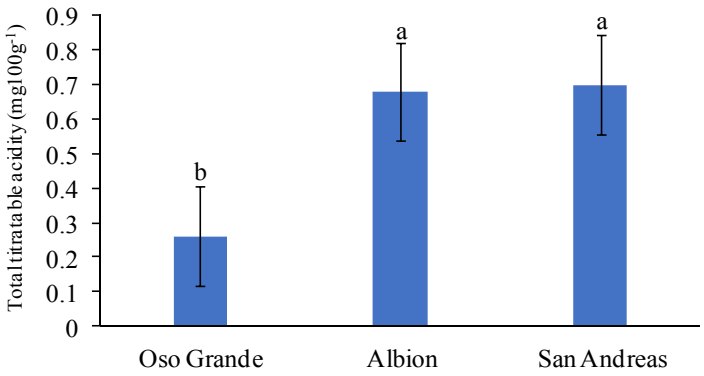

Fig. 9. Total Titratable Acidity of commercial fruits of three strawberry varieties under semi-hydroponic crop systems

Fruit acidity of San Andreas and Albion varieties fits within an acceptable range (0.73 - 1.58 %) [21], which shows that despite their lower yields, the yield quality is good. Total acidity regarding the Oso Grande cultivar did not meet the standards values, possibly because of its low adaptability to local climatic conditions. Fruit quality measured on that variety was higher than that determined in Minas Gerais region (0.65%) [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 have declared that no competing interests exist.

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http://sciencedomain.org/review-history/22483