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Evaluation effects of alternative substrates for soilless cultivation of strawberry (Fragaria x ananassa)

Evaluación de efectos de sustratos alternativos para el cultivo sin suelo de fresa (Fragaria x ananassa)

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ABSTRACT

Strawberry is one of the major cultivations in Mexico, nonetheless, low development of planting techniques reduces fruit quality. The present research aimed to evaluate alternative substrates for soilless cultivation of strawberry, variety festival (*Fragaria x annanasa*). Four substrates were evaluated to achieve the goal: T1 coconut fiber substrate, T2 volcanic rock "tezontle", T3 coconut fiber 50 % volcanic rock "tezontle" 50 %, and T4 soil as control. To compare the substrates, some properties that people chose in the fruit were selected: number of fruits per plant, fruit weight, fruit size, and Brix degrees (° Brix). The ° Brix did not show differences among the treatments; however, under T2 and T3 the best results were observed in terms of the number of fruits per plant, fruit weight and fruit size, which are considered remarkable market fruit qualities. In all the cases, T4 showed the lowest values in comparison to the other substrates. In conclusion, due to its low-cost volcanic rock alone or combined with coconut fiber could be used as a promising substrate for the production of strawberries; however, further work is needed to optimize other factors such as fertilization regimes and irrigation to reduce the production cost in a soilless production system.

Keywords: coconut fiber, tezontle, volcanic rock, berry, soilless

RESUMEN

La fresa es un cultivo destacado en México, no obstante, presenta bajo desarrollo en técnicas de siembra lo que afecta la calidad de la fruta. La presente investigación tuvo como objetivo evaluar sustratos alternativos al suelo para el cultivo de fresa variedad festival (*Fragaria x annanasa*). Se evaluaron cuatro sustratos para lograr el objetivo: T1 sustrato fibra de coco, T2 roca volcánica "tezontle", T3 fibra de coco 50 % roca volcánica "tezontle" 50 % y T4 suelo como control. Para comparar los sustratos se seleccionaron algunas propiedades que las personas eligen en el fruto: número de frutos por planta, peso del fruto, tamaño del fruto y grados Brix (°Brix). Los °Brix no presentaron diferencias entre los tratamientos; sin embargo, bajo T2 y T3 se observaron los mejores resultados en cuanto a número de frutos por planta, peso de fruto y tamaño de fruto, los cuales se consideran cualidades notables del fruto en el mercado. En todos los casos, T4 mostró los valores más bajos en comparación con los otros sustratos. En conclusión, debido a su bajo costo, la roca volcánica sola o combinada con fibra de coco podría ser utilizada como un sustrato promisorio para la producción de fresas; sin embargo, se necesita más trabajo para optimizar otros factores como los regímenes de fertilización y riego para reducir el costo de producción en un sistema de producción sin suelo.

Palabras clave: fibra coco, tezontle, roca volcánica, baya, sin suelo

1. INTRODUCTION

The strawberry is a valuable fruit in the Mexican economy where production has increased twice in the last ten years and globally Mexico is the third producer with over 557, 514 tons produced in 2020. Besides 306,520 tons are sold abroad and the United States is the major consumer destiny with 95 % of exportations while the rest is sent to other countries such as Canada, Hong Kong, Saudi Arabia, Japan, Kuwait, United Arab Emirates, Peru, Panama, Chile and Nicaragua (SIAP, 2020).

However, despite being an attractive agricultural product in the global market, strawberry cultivation still struggles with some challenges, to name some, during 2020 production reduced by 35.3 % in contrast to 2019 due to lower production areas and low growth yields (SIAP, 2020). There is none to mention recent increases in fertilizer prices and low-tech cultivation practices among most Mexican growers.
Strawberry cultivation systems can be classified based on their technical level or degree of technology, which affects their yields (Alvarado Chávez, 2018). It can be classified as low-tech systems that are developed under open-field production conditions and temporal or gravity irrigation and those that achieve less than 25 tons per hectare, followed by medium-tech systems with medium technology such as drip irrigation and the use of mulch where productivity is around 40 tons per hectare, finally the high-tech systems that are implemented inside greenhouse facilities which are capable to achieve productions between 70-90 tons per hectare.

Despite the clear advantages of technology adoption in cultivation practices, 94 % of production in the country is generated under open-field production conditions with low technical levels, and the highest yields round less than 40 tons per hectare (Alvarado Chávez, 2018). Therefore, it is evident that contributions are required to improve strawberry production, such as the use of nutrient solutions to sustain physiological demands (Cooper, 2002), or the replacement of soil in the cultivation practice. Soil cultivation is responsible for lower productivities in strawberries associated with soilborne diseases such as *Verticillium* wilt, *Phytophthora* crown, and root rot, black root rot, and charcoal rot caused by *Verticillium dahliae*, *Phytophthora cactorum*, *Cylindrocarpon destructans*, *Macrophomina phaseolina*, respectively (Zahid *et al*., 2021).

The replacement of soil cultivation techniques with soilless growing systems with alternative substrates need to be developed as technological strategy to improve fruit qualities or develop new agriculture technique (Gruda, 2019). Some substrates such as volcanic or organic substrates, have attractive characteristics for nutrient availability due to their chemical, physical and hydraulic properties (Wang *et al*., 2016). Thus, in contrast to soil, the use of substrates such as gravel, compost, sand, perlite, sawdust, or coconut fiber can be employed (Resh, 2001). Nonetheless, to choose the proper substrate, it is necessary to test its effectiveness in plant development and other valuable characteristics of the desired product. The present project aimed to determine the effect of soilless substrates on the quality and physical properties of strawberries fruit variety festival (*Fragaria x annanasa*).

2. METHODOLOGY

2.1 Experimental location

The experiment was conducted at Instituto Tecnologico Superior de Libres in Libres, Puebla, México. The municipality of Libres is located between 19° 21' 19" north latitude and 97° 32' 48" west longitude, at an altitude between 2,320 and 3,400 m, temperature between 10-16 ° C, precipitation 400-900 mm, the predominant climate is temperate subhumid with rains in summer (INEGI, 2010). During the experimental stage the experiments were developed inside a greenhouse facility between September 2021 and January 2022. This greenhouse is normally employed for the production of ornamental plant species such as *Zantedeschia aethiopica*, roses, and cetaceous species.

2.2 Experimental establishment

A randomized complete block design was employed, which consisted in three blocks that contained the four treatments each, every treatment consisted of pots with five plants per treatment, for a total of 15 plants per treatment. Thus plants were planted in wood pots 1 m long, 0.5 m wide, 0.5 m high, filled with the corresponding substrate (Figure 1). The four substrates corresponded to: Treatment 1 (T1): coconut fiber substrate (70 % fiber, 30 % powder); Treatment 2 (T2): volcanic rock "tezontle" substrate (2-4 mm); Treatment 3 (T3): coconut fiber 50 % / volcanic rock "tezontle" 50 % substrate, this was a mixture at 50% ratio of each substrate; Treatment 4 (T4): soils as control substrate. The volcanic rock "tezontle" was used as a substrate of its high availability in Mexico as it is normally used in floriculture production (Trejo-Tellez *et al*., 2013). When coconut fiber was used, the substrate was previously washed with distilled water to reduce the electric conductivity and pH from 3.80 and 6.55 to 1.60 and 5.6 respectively; these measurements were recorded using a HANNA instrument.

During the experimental period, strawberry plants received nutrition by the addition of a nutritional solution. Nutrient solution was prepared in 0.2 m^3 tank, this contained (gL^{-1}): 0.1 $Ca(NO)_2$, 0.05 KNO_3, 0.075 K_2SO_4, 0.225 $MgSO_4 \cdot 7H_2O$, 0.0675 $NH_4H_2PO_4$ and 0.02 Ultrasol® microMix to provide micronutrients into the solution. Finally, pH was adjusted by adding sulfuric acid to achieve a value of 5.6. This nutritional solution was applied manually every third day at a reason of 3 L per plant and after three additions only water was applied to avoid the increase in electrical conductivity.

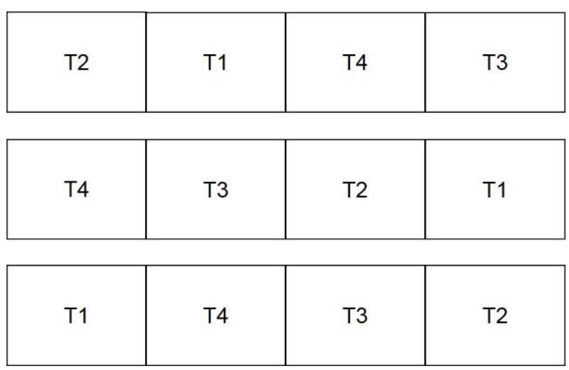

Figure 1. Experimental design to test the effect of different substrates during strawberry growth (T1 coconut fiber substrate, T2 volcanic rock "tezontle", T3 coconut fiber 50 %/volcanic rock "tezontle" 50 %, and T4 soil).

2.3 Fruit physical and quality properties assessment

The number of fruits, soluble solids (° Brix), and physical measurements were recorded to determine fruit quality and physical properties. The fruit number was recorded right after the emergence of fruits, while Soluble solids (° Brix) were analyzed with a refractometer (HANNA HI96801). The weight was recorded using a precision balance and a Vernier was employed to measure the equatorial and polar diameter of the strawberry fruit.

3.4 Statistical design and analysis

Statistical analysis was performed using Minitab software (Version 19 for Windows). The analysis of variance (ANOVA) and the Tukey test ($p \leq 0.05$) were used to identify differences among substrates.

3. RESULTS AND DISCUSSION

3.1 Plant establishment and care

During the experiment 2 leaf prunings were carried out, to remove old leaves. The removal was necessary since the plant could have suffered stress from the transplant because the plants came from a colder place with a higher altitude than the one in the new location.

Additionally, during the experimental stage spider mites "*Tetranychus urticae*" were observed in the strawberry leaves (Figure 2), thus the plague was initially controlled with a biological control powder which contains spores and metabolites of *Bacillus thuringiensis*. However, the biological treatment did not affect the *T. urticae* and thus sulfur was applied to kill the pest. This proper pest control was carried during 60 days before the experiment to eradicate *T. urticae* which could produce harmful effects on the strawberry plants (Sances *et al*., 1982). Therefore, *T. urticae* did not cause any damage to the strawberry plants during the experimental stage.

Figure 2. Spider mites (*Tetranychus urticae*) were observed and eradicate from the strawberry plants.

3.2 Fruit physical and quality properties assessment

The physical and quality properties of strawberry fruits that grow under different substrates are observed in Table 1. It can be observed that ° Brix did not present any significant variation as the effect of different substrate compositions. Nonetheless, ° Brix was the unique property not affected, since the other properties showed significant differences. In terms of fruits per plant, the highest values were observed under both the treatment 3, which corresponded to the mixture of coconut and volcanic rock, and treatment 2 of volcanic rock, followed by the soil treatment (T4), finally, it was unexpected to obtain the lowest value in coconut fiber since some reports have recommended this substrate as one of the more promising for strawberry production under soilless cultivation systems because of its high water retention and aeration properties (Lopez-Medina *et al*., 2004; Wang *et al*., 2006). This low value could be due to compaction of the coconut fiber substrate which could reduce the rhizospheric zone and decreased the fruit productivity. In the fruit weight value, T3 reported the highest observed value, followed by T2, meanwhile, the lowest average values were observed in both T1 and T4. In the polar diameter, the highest values were observed in all soilless substrates and the lowest was observed in soil planting. Finally, similarly to polar diameter, the lowest equatorial diameter was observed in the soil substrate and the highest in both the mixture and volcanic rock, followed by the coconut fiber substrate. In general, the highest physical values were observed in the mixture of coconut fiber and volcanic rock, this observation is very similar to other authors who observed the best physical values of strawberry fruit using a combination of coconut fiber with other materials high in porosity (Nihad *et al*., 2018; Maher *et al*., 2020). These differences could be due to soilless substrates avoiding rapid compaction as in the case of soil since strawberry plants depend greatly on their roots' density (Bartczak *et al*., 2007). The combination of coconut fiber with volcanic rock alone demonstrated high physical values, especially when compared with the values of fruits per plant and fruit weight observed in coconut fiber alone for treatment 1. Volcanic rock "Tezontle" is considered inert material with pH values near neutrality, low conductivity, good aeration, and moisture-holding capacity (Trejo-Tellez *et al*., 2013) additionally it is an abundant material and low cost in Mexico (Ponce-Lira *et al*., 2013) thus its use as the substrate is very convenient for strawberry cultivation not only for its low cost but also for improvement in physical fruit qualities.

Table 1**.** Fruit physical and quality properties under different substrates, A) T1 coconut fiber substrate, B) T2 volcanic rock "tezontle", C) T3 coconut fiber 50 %/volcanic rock "tezontle" 50 %, and D) T4 soil as substrate.

Treatment	Brix degrees (° Brix)	Fruits per plant	Fruit weight (g)	Polar diameter (mm)	Equatorial diameter (mm)
T1	7.85±1.31	14.00±5.00 b	14.17±1.44 b	42.12±2.61 a	30.07±0.98 b
T2	8.43±1.14	32.33± 5.77 a	15.83±1.44 ab	39.03±3.27 ab	33.66±0.32 a
T3	7.70±0.53	33.33±4.16 a	18.33±1.44 a	41.53±2.74 a	32.51±0.86 ab
T4	8.17±0.65	22.33±2.31 ab	12.50±2.50 b	35.32±1.86 b	27.01±2.02 c

Means followed by the same letter indicate no significant differences according to the Tukey test ($P<0.05$).

As mentioned previously, the low results observed under coconut fiber alone as substrate were not expected since it is one of the most used substrates in horticulture production. Therefore, it was suspected that coconut fiber loss small particles and reduced the space for rooting decreasing strawberry growth. This hypothesis came from similar work performed by Rivera-del Rio *et al*., (2017) in experiments to test hydroponic production of strawberries using different substrates, where it was observed that volcanic rock increased the easily available water and maintained bulk density, porosity, and aeration capacity, in contrast coconut fiber showed the greatest change in particle size.

The research for alternative soilless cultivation substrates for strawberry production has increased recently (Sharma & Godora 2017; Manabika Sheel *et al*., 2019; Hoehne *et al*., 2020), this is due to the high value of fruit and the development of alternatives to conventional cultivation techniques. In the present work it was observed and increment using soilless substrates in both fruit weight and polar-equatorial diameter, which are physical properties involved in the selection by consumers (Bhat *et al*., 2015). The improvement of any of these physical properties could increase the value of commercial strawberry plantations for exportation and the product value. Under different substrates, it was observed physical differences among strawberries (Figure 3). Soil planting strawberries reported the lowest sizes and weight in comparison to the other soilless substrates. Thus the use of soilless substrates not only could reduce the damages associated with soil pests but also could improve the physical appearance of strawberry fruit, this is in agreement with other authors who observed improvement in strawberry fruits due to the cultivation of soilless substrates (Bartczak *et al*., 2007; Nihad *et al*., 2018; Maher *et al*., 2020), this is expected to improve the strawberry production and then lead to new technological adaptations and markets such as organic production which could increase the value in the market (Yavari *et al*., 2008). Finally, although °Brix did no increased, it is more desirable to improve yield and physical properties in strawberry fruit, since it has been reported that any increment of sugar content is correlated with lower production yields (Ulrich & Olbricht 2016). Since sugar content was the same under different substrates, the physical qualities and number of fruits per plant increased using any soilless substrates, thus it was concluded that volcanic rock "tezontle", alone or combined with coconut fiber, is a potential alternative with advantages for the productions of strawberry cultivation.

Figure 3. Strawberry fruits, physical appearance under different substrates, A) T1 coconut fiber substrate, B) T2 volcanic rock “tezontle”, C) T3 coconut fiber 50 %/volcanic rock “tezontle” 50 %, and D) T4 soil as substrate.

4. CONCLUSIONES

As a result of the analysis of variance and the Tukey test, we concluded that the least favorable substrate was the soil. Coconut fiber, although it presented good results in weight, polar and equatorial diameter, was the one with the lowest number of fruits per plant. Therefore, as a result of this experiment, we concluded that the substrates coconut fiber-tezontle or tezontle alone, were the ones that showed the best results in terms of number of fruits, fruit weight, and polar-equatorial diameter. Brix degrees were not affected by the use of the substrate; however, visible characteristics were affected, and some of them are important when consumers choose fruits. It is important to highlight tezontle as a potential soilless substrate for strawberry cultivation, due to its low cost and high abundance in Mexico.

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