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AGRICULTURAL PRODUCTION

Effect of the roof (Low tunnel) on the productivity of two varieties of strawberry (Fragaria vesca) in Cajanuma, Loja

Efecto de la cubierta (microtúnel) en la productividad de dos variedades de fresa (Fragaria vesca) en el sector Cajanuma cantón Loja

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Resumen

La fresa (*Fragaria vesca*) es un cultivo de gran aceptación a nivel mundial, no siendo la excepción en Ecuador. La mayor parte de la producción se realiza a campo abierto, haciendo que existan limitaciones por el ataque de factores bióticos y la influencia de factores abióticos, generando pérdidas en la producción. El presente trabajo se planteó en la provincia de Loja al no existir información precisa de este cultivo e investigaciones sobre el uso de sistemas protegidos (microtúnel). El objetivo principal fue evaluar el efecto de la producción de fresa en los dos sistemas de producción (Campo abierto y microtúnel), con variedades Albion y Monterey; además analizar el costo y rentabilidad de la producción. El sistema a campo abierto fue considerado como un tratamiento testigo para su evaluación frente al de microtunel. El experimento se realizó en la Estación Agropecuaria de la Universidad Técnica Particular de Loja, bajo condiciones de microtúnel y campo abierto, en la cuales se comparó el desarrollo fenológico y productivo de la fresa. Los resultados encontrados en el estudio en los dos sistemas a campo abierto y microtúnel no presentaron una diferencia estadística en las variables fisiológicas evaluadas, concluyendo que la cubierta con microtúnel al cultivo no influyó en el desarrollo en las dos variedades. En relación al análisis de costos-beneficio de la producción, este fue superior en el sistema microtúnel, la inversión fue más fuerte al inicio, sin embargo, se debe indicar que existen varias ventajas productivas en relación con campo abierto, generando beneficios al productor de fresa.
Palabras clave: Fresa, Microtúnel, producción, rendimiento, rentabilidad.

Abstract

The strawberry (*Fragaria vesca*) is a crop of great acceptance worldwide. In Ecuador, most of the production is done in open field, presenting limitations by the attack of biotic factors and abiotic factors that generate losses in the production. This research was carried out in the province of Loja, since there was no precise information on this crop, and research on the use of protected systems (low tunnels). The main objective of the study was to evaluate the effect of strawberry production on the two production systems (open field and low tunnels), with Albion and Monterey varieties, as well as to analyze the costs and profitability of production. The experiment was conducted at the Agricultural Station of Universidad Técnica Particular de Loja, under low tunnels and open field conditions, in which the phenological and productive development of the strawberry was compared. The results found in the study in the two open field and low tunnel systems did not present a statistical difference in the physiological variables evaluated, which allow to conclude that the low tunnel cover on the crop did not influence the development of the two varieties. In relation to the cost-benefit analysis of production, it was higher in the low tunnel system, the investment was stronger at the beginning, but it must be indicated that there are several productive advantages in relation to the open field that generate benefits for the strawberry producer.
Keywords: Low tunnels, production, profitability, strawberry yield.

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1 Introduction

The crop of strawberry by agricultural producers and its consumption has a very good acceptance worldwide (Khoshnevisan et al., 2013), the same happens in Ecuador, where it has started to be part of the family consumption (Vizcaino, 2011). The fruit is quite attractive to the consumer for its aroma and exquisite taste; it also has a lot of vitamins, minerals and organic acids, acting as disinfectants and anti-inflammatory drugs that decreases cholesterol. In addition, essential oils can be extracted, and their consumption can be fresh or processed (Karim et al., 2011; Giampieri et al., 2012; Pradas et al., 2015; Bernarda and Bawab, 2017; Estrada et al., 2017). Strawberry is characterized by being herbaceous and perennial, it is very sensitive to environmental conditions and its development is subjected to the climatic characteristics, chemical, physical and structural properties of the soil (Ferriol, 2010; López et al., 2011; Pineda, 2017). There are short-day varieties subjected to photoperiod, fewer hours of light for the development of flower buds; and neutral-day varieties that are not subjected to photoperiod for the development of flower buds (Undurraga and Vargas, 2013; Pérez et al., 2017).

The mostly used production systems are open field and under protection (Rubio et al., 2014). Open field production is highly susceptible to biotic and abiotic factors such as pests, diseases, high temperatures, precipitation, winds and frosts (Dominí, 2012; Pineda, 2017), which can affect productivity. Lamont and William (2009) mention that technology helps to have better control of the climatic conditions for its cultivation. Environmental, genetic and variety factors are important in the plant growth, productivity and fruit quality (Rodríguez et al., 2012). The cultivation of strawberry in protected systems such as the low tunnel system can be an alternative in the production of this crop, because these systems have some advantages such as low cost, small size and practicality of installation (Juárez et al., 2011; Pernuzz et al., 2016), compared to other protected systems such as greenhouses.

In Ecuador an area of 108 ha is harvested, reaching a yield of 16.27 T/ha, being very low compared to other strawberry producing countries, such as the United States with 66.90 T/ha of production; Spain (47.6 T/ha); Egypt 46.6 T/ha; Israel with 43.5 T/ha, and Colombia with 36.5 T/ha of strawberry production per year (Corrêa and Peres, 2013; FAOSTAT, 2016). However, in the last decade it has had an interesting growth, either by adopting new technology or new varieties.

The search and application of new innovations in agricultural production to improve production systems are very important, since each area dedicated to strawberry cultivation has its common features. In the province of Loja, it is necessary to carry out research on the subject in the absence of accurate information or research on the use of protected systems (low tunnel) in this crop. Therefore, this study aims to assess the effect of the use of protection (low tunnel) on the development and productivity of strawberry cultivation in the Albion and Monterey varieties, which are the most commercialized in this area, in order to analyze the most feasible alternatives, so that smallholder farmers at the local level increase yield and economic benefits.

2 Materials and Methods

2.1 Study area

This study was carried out in the province of Loja – Ecuador, at the Agricultural Station of the Technical University of Loja, located in the Cajanuma sector, 9 km away from the city, with the X coordinates: $-4{,}0887$ Y: $-79{,}2082$ (Google Maps, 2018). at an altitude of approximately 2230 m.a.s.l; an average temperature of 16 $^{\circ}C$ and an average rainfall of 780 mm/m^2 according to data from Estación meteorológica «La Argelia» (2017).

2.2 Experimental design

The study area is a place with homogeneous topography and edaphoclimatic characteristics. Four plots (treatments) were established under an experimental design of complete blocks. The established treatments were: two low cover (low tunnel) in which the Monterey and Albion varieties were grown (one variety in each low tunnel), and the same treatments were established in open field (without cover). Each treatment had a total of 54 plants (F1) and each was considered as an experimental unit (Pernuzz et al., 2016).

The symbols established for the treatments were: **CAV1**= Open field treatment monterey variety, **CAV2** = Open field treatment albion variety, **MTV1** = low tunnel system treatment monterey variety, **MTV2** = low tunnel system treatment albion variety. The size of the low tunnels was 8 m long × 1 m wide and 0.90 m high, with polyethylene plastic cover Nro 8. A planting density of 0.30 × 0.40 m between row and plant (54 plants per treatment) was used in each treatment.

The fertilization was similar in all treatments, using organic fertilizer (BioCompost) at the time of transplantation (250 g/plant), and mineral fertilizers based on $N - P_2O_5 - K_2O - MgO - CaO - S$ ($200 - 200 - 300 - 40 - 100 - 40$ Kg/ha, respectively), all based on soil analyses and crop needs (Patiño et al., 2013; Avitia et al., 2014).

The irrigation system was installed by low flow drip, with vortex emitters inserted and flow output 2 to 4 Lt/hour, and was watered based on the weather conditions, as commonly handled by farmers in the area. The integrated management of pests and diseases (MIP) was thorough, each plant was monitored, preemptively performing sanitation pruning to avoid diseases such as *Botrytis cinerea*, *Colletotrichun* sp. y de *Trips* sp. (Santoyo and Martinez, 2010).

2.3 Variables evaluated

The evaluation variables are detailed below: **Detachment percentage:** it was performed by counting the total of plants (experimental unit) of each treatment that was successful in its detachment, indicating that the results were expressed as percentage (Ibadango, 2017).
Number of flowers: The number of flowers on each plant of the four treatments was counted; this data was recorded throughout the project evaluation (Yaselga, 2015).
Number of fruits: The amount of fruits in the plants of each treatment was determined for a period of 6 months, the data were recorded daily in order to have more detail of the productivity by production system and variety of cultivated strawberries (Ibadango, 2017).
Fruit diameter: The data was taken from the fruits harvested with a Vernier calibrator, the measurement was done from the central part of the fruit (unfructescence), expressing the values in centimeters (Verdugo, 2011).
Fruit weight: The weight of each harvested fruit was considered. It should be mentioned that strawberry fruits were harvested when they were ripe, just as the registration of the previous variables, this was done daily once the production started (Verdugo, 2011).
Economic analysis of strawberry production: The production of the crop was calculated taking into account the total harvested (without considering the losses), and the final production of the treatments was transferred and expressed in kg/ha.

The net income (benefit) of these production systems in this study was estimated with the difference between the input and costs of strawberry production (Cost/benefit (C/B) = Input/expenses) (Infante Villarreal, 1984), calculating inputs from sales of the fruit at average MAG (2018). Total costs were estimated from the average planting costs and its management: fertilization, weed control, irrigation system, pest control, diseases, pruning, among others.

2.4 Statistical analysis

The normality or abnormality of the data was checked with KS tests to establish statistical differences in the measured parameters (variables), then one-way ANOVA was applied with homogeneous Tukey tests at a significance level $p < 0,05$, for this the statistical software SPSS 24.0 was used.

3 Results and discussion

Table 1 details the results obtained in the different treatments. It is observed that there are not significant statistical differences between the physiological variables evaluated, indicating that the cover of low tunnel did not influence the development of strawberry cultivation in the two varieties, probably because there were no heavy periods of rain.

Table 1. Percentage of detachment, number of flowers, number of fruits, fruit diameter and weight of *Fragaria vesca* fruit in the evaluated treatments.

Parameters	CAV1	CAV2	MTV1	MTV2
%Detachment	94.45 ± 0.23 a	94.45 ± 0.23 a	100.00 ± 0.00 a	98.15 ± 0.13 a
Number of flowers	37.92 ± 7.20 a	34.85 ± 6.70 a	37.35 ± 8.83 a	36.57 ± 7.53 a
Number of fruits	36.20 ± 7.87 a	34.57 ± 6.78 a	36.62 ± 6.63 a	35.07 ± 9.11 a
Fruit diameter (cm)	3.26 ± 0.39 a	3.29 ± 1.11 a	3.26 ± 0.32 a	3.30 ± 1.09 a
Fruit weight (g)	23.74 ± 6.60 a	23.79 ± 6.74 a	23,94 ± 5,59 a	23,95 ± 7,06 a

Table 1 shows the mean data and standard deviation of the percentage of the detachment, number of flowers, number of fruits, fruit diameter (cm/fruit) and fruit weight (g/fruit). Different lowercase letters indicate significant statistical difference between treatments. CAV1 = Open field treatment variety monterey, CAV2 = Open field treatment variety albion, MTV1 = low tunnel system treatment variety monterey, MTV2 = low tunnel system treatment variety albion.

The high percentages of the detachment in this study is possibly due to the good agrotechnical management in the crop, thus complying with all the standards of good agricultural practices. This work reinforces what is indicated by Montero (2016) y Yaselga (2015), who say that a proper irrigation treatment, a substrate enriched with abundant organic matter, adequate pest and disease control and proper soil disinfection facilitated seedlings' detachment; hence, their adaptability, which is directly related to the percentage of seedling detachment. In addition to this, Nin et al. (2018) mentioned that it is recommended to adjust the crop date according to light/temperature conditions for a better seedling survival, in order to control the interactions between the plant and the environment. The percentage of the crop's production played an important role in the fruit production by the number of live plants in each treatment.

Moreover, the number of flowers/plant in all installed treatments showed no significant statistical differences between treatments. If comparing this study with that of Juárez et al. (2007), the number of flowers was high, since the study carried out by the aforementioned authors obtained a smaller number (five flowers/plant), attributing this low number of flowers to climate factors that were not right for the crop, indicating that plants are sensitive to the effect of the photoperiod and high temperatures, which could have influenced these differences.

Likewise, León et al. (2014), mention that nutritional requirements in strawberry crop are essential for its floral development; thus, a good nutrition plan made according to the crop requirements and the soil quality also supported that the number of flowers are high in this research, regardless the treatment applied. Authors such as Caruso et al. (2011) indicate that photosynthesis influences the number of flowers, which would be influencing to obtain these results. In addition, being located in the center of the earth with approximately 12 hours of light exposure has also played an essential role in this study, which contributed to the good flowering of the crop in the two production systems.

The variable numbers of fruit/plant in this study (Table 1), for the evaluation of the first productions have been considered acceptable. It should be noted that these are directly related to the number of flowers. The results obtained are similar to those presented by Montero (2016) y Radin et al. (2011) who found 29 and 37 fruits/plant, respectively. It is worth mentioning that Montero's research was carried out at Sierra del Ecuador, with conditions similar to the province of Loja. The aforementioned authors suggest that it should be taken into account the influence of environmental factors such as water deficit, temperature, solar radiation, among others with the aim of obtaining a good number of fruits. This means that relatively low and high temperature changes, relative to the ideal temperature range which is between 18 and 25 $^{\circ}C$, negatively affect the fruits set (Ledesma et al., 2008). Another very important factor to consider for a better production is the health and nutrition of plants, in addition to what is indicated by Poveda et al. (2018) who mentioned that wind and the presence of pollinating insects also have significant influence to obtain a greater number of fruits with good quality whether in the open field or under protection, as it is in this case.

The average diameter of the fruit in each of the treatments (Table 1), similar to the other parameters evaluated, has shown no significant differences. The diameter has a direct relationship to the weight of the fruit. Hollender et al. (2012) mention that the diameter varies depending on the number of carpels and the number of achenes present in the fruit; the achenes splash the surface of the receptacle and produce auxins to stimulate growth. Similarly, Ledesma et al. (2008) indicate that when achenes are not properly fertilized, the development of the area in the fruit around the achenes is inhibited, which is observed in the malformation of the whole fruit and is evidenced in the diameter of the fruit. This is consistent with this study, as the diameter of the fruit did not vary because of the same fertility doses in all treatments. On the other hand, Radin et al. (2011), mention that insufficient pollination and damage caused by insects produces the malformation of the strawberrys fruit, which was not presented in this study due to strict monitoring and control of the crop in all treatments. However, this data should be taken into account for plantations of commercial areas or bigger plantations.

As regards the fruit weight variable, no difference was found between the treatments (Table 1). These results are similar to those found by Ibadango (2017) which also shows that there are no differences in the average weight of strawberry fruit grown under a protected system and under an open field. In another study they state that the weight of the fruits will mainly depend on the nutritional status of the plants and the total soluble solids, which are characteristics dependent on the variety (Ortiz et al., 2016); This is consistent with this study, while having the same treatments in fertilization, has shown no difference in the weights of strawberry fruits produced under low tunnel and open field. This is further corroborated by the study conducted by Vignolo et al. (2011), who found significant differences in the average weight of the fruit, testing different doses of manure and fertilization. Another cause that can attribute more or less weight to the fruits is what Radin et al. (2011), indicated when saying that weight is related to the variety grown, and that the difference between the average weight per fruit may be associated with genetic factors, without neglecting the conditions of the environment.

3.1 Productive and economic analysis of the crop

Figure 1 shows the total production of the different strawberry treatments evaluated in this study, expressed in Kg/ha/year. Higher net production was obtained in the low tunnel system in the two varieties, with a significant statistical difference compared to open field production. These results are in agreement with the studies conducted in Colombia by Grijalba et al. (2015), who obtained higher productions in low tunnel systems (1260 g/plant) than in open field (1197 g/plant), being the ratio for the same time period as that of this research (840 g/plant open field system and 860 g/plant low tunnel system). Grijalba et al. (2015) say that this increased production occurred since there was lower incidence of pest and diseases in their protected crops.

The growing system (open field or under cover) can play an important role in the yield, such as in the fruit quality (Nin et al., 2018). In addition, productivity is related to two characteristics of the crop, the average weight of fruits and the number of fruits produced per plant throughout the cycle (Otto et al., 2009), a figure that matches the fruit weights obtained in this work. While there were no significant differences between treatments (Table 1), the weight of the fruits produced under the greenhouse was higher, which has been expressed in better total production.

According to Pernuzz et al. (2016) in its comparison study in micro and macrotunnel production systems, the low tunnel system has a higher net production compared to that of this study, which reached 45950 kg/ha; however, it continues to confirm the hypothesis of good production results when growing under low tunnels or under cover. In addition, they indicate that low production in the open field system may be due to the impact of weather conditions during the harvest, making the crop to be more attacked by pests and diseases.

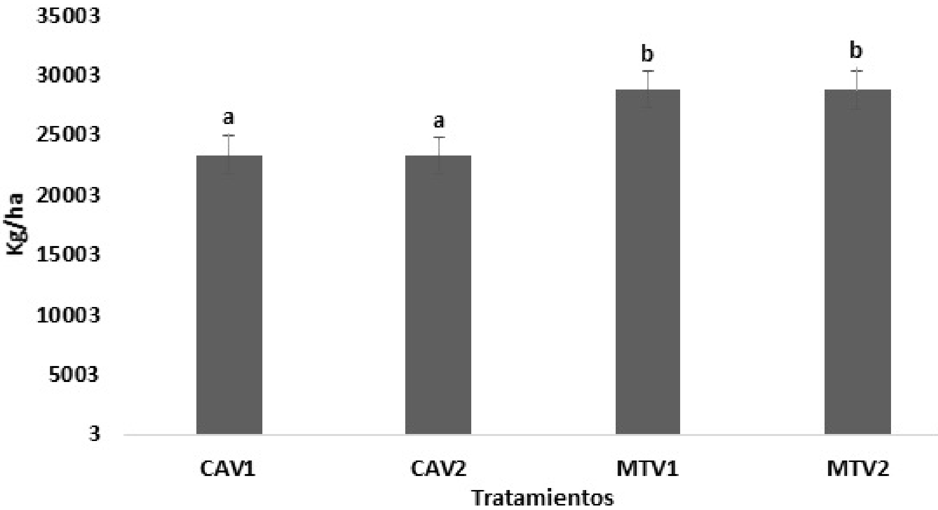

Figure 1. Net production (kg/ha/year) of *Fragaria vesca* in the evaluated treatments.
Note: Final production expressed in one kg/ha is presented. The bars represent the mean of each treatment with their corresponding standard deviation. Different lowercase letters mean significant statistical difference. CAV1 = Open field treatment variety monterey, CAV2 = Open field treatment variety albion, MTV1 = low tunnel system treatment variety monterey, MTV2 = low tunnel system treatment variety albion.

In the study conducted by Rubio et al. (2014),there is a higher number of disease attacks in the open field system, being mainly affected by *Botrytis cinerea*, *Sphaerotheca macularis*, which directly affects net production, versus a protected and least attacked system; this because the humidity is lower in the protected system, and the production losses are lower. Similarly, the attack by lepidoptera and mites affected the protected system, because in that study the net production was lower than in this study, since they obtained 15365 kg/ha in open field and 20070 kg/ha in protected system, being one of the possible causes even to the productive reduction in both systems. The net yields in this study, when compared to the data of the aforementioned authors, are good and acceptable, being up to 10 % higher than the production obtained Rubio et al. (2014), and about 30 % higher over Ecuador's average net production. However, these values are lower than those of other countries such as Colombia, which has a production of around 40000 Kg/ha.

3.2 Cost-benefit (C/B).

Table 2 shows the cost-benefit per ha/year of production for all treatments. It is evident that the open field system and protected low tunnel system are very similar in the first year of production in its C/B ratio: 1.57 versus 1.59, respectively. In either system the investment would be profitable within this first year. However, it must be considered that the investment costs in low tunnel systems have been higher because of the initial infrastructure required; but, given the good production obtained, its cost-benefit ratio is positive as shown in Table 2. Following this year 1 production pattern in the protected production system, it is assumed that the potential economic benefits in subsequent years should be higher in this production system (low tunnel), as infrastructure investments would reduce considerably, so its use would be advisable. In addition, these systems are an option to crop in areas with adverse weather conditions to the climatic requirements of the crop, such as constant frosts, low temperatures or heavy rainfall (Rowley et al., 2010).

The crop production is directly related to economic benefit, which is an important factor for a better profitability. On the other hand, Caruso et al. (2011) mention that the yield is one of the basic factors for improving revenue, although they indicate that product quality is also another factor, as in many markets quality is a desired value. However, in many cases producers do not have a satisfactory benefit, their profitability for the production of this crop is low or zero, which is mainly attributed to the high production costs (Pineda, 2017), and even more in the initial part of a protected system. However, as indicated by Pernuzz et al. (2016), it should be considered that the protected system has a lifespan of about 10 years, except for plastic casings that could be useful on an average of 5 years, being a benefit in crop production, which will be reflected in long-term net gain. On the other hand, it is also necessary to consider what is stated by Rubio et al. (2014), who mention, from the investment point of view, that the value of open field losses in each cycle is about one-fifth of what it costs to make the investment to build the protected system; thus, many producers as not to risk capital decide to opt for a traditional production system and make lower profits.

Table 2. Relationship of the cost-benefit of *Fragaria vesca* in treatments, expressed in ha/year of production.

Treatments	Income (USD)	Expenses (USD)	Benefit (USD)	Cost Benefit Relationship
CAV1	276777,77	175638,88	101138,89	1,57
CAV2	276740,74	175638,88	101101,86	1,57
MTV1	342324,07	215055,55	127268,52	1,59
MTV2	342101,85	215055,55	127046,30	1,59

Table 2 shows the income, income, benefit and cost-benefit data from the evaluated treatments. CAV1 = Open field treatment variety monterey, CAV2 = Open field treatment variety albion, MTV1 = low tunnel system treatment variety monterey, MTV2 = low tunnel system treatment variety albion.

4 Conclusions

In this case, in the two production systems (traditional-open field and under cover), there was no statistically significant difference in the physiological variables evaluated ($p < 0,05$). However, it should be noted that as the weight of the fruits of the system under low tunnel is greater, this has been reflected in higher final net production per ha, being this production higher than in the open field.

In the production cost-benefit analysis, the investment in the low tunnel system was higher compared to the open field system. However, it should be noted that the benefits of low tunnels, in terms of their improved productivity, ease of handling and even durability of infrastructure, generate greater economic benefits to the producer in the medium and long term.

The use of low tunnels in strawberry production is a viable option for smallholder farmers, especially when weather conditions are not recommended to the climatic requirements of the crop, as well as the possibility of achieving up to 30 % better production versus the national average.

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