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Evaluación de alternativas de fertilización sostenibles en el cultivo de fresa var. Albión en condiciones de campo en Ecuador.

Evaluation of sustainable alternatives of fertilization in strawberry var. Albion under field conditions in Ecuador.

García Bolívar, Judith Josefina*; Riofrio Fuelagan, Edison Andrés.
Universidad Politécnica Estatal del Carchi, Av. Universitaria y Antisana, Tulcán, Ecuador.
*garciaj66@gmail.com

Resumen

Esta investigación duró diez meses; seis meses fueron para el desarrollo de las plantas y cuatro meses para la cosecha, las unidades experimentales fueron camas de 10 m de largo con 40 plantas, la distancia entre plantas fue de 40 cm. Se realizaron tres experimentos simultáneamente en el mismo sitio. El Experimento A evaluó cinco tratamientos aplicados mensualmente; cuatro orgánicos y uno químico (testigo), fueron Vermicompost, Micorrizas, Microorganismos autóctonos eficientes (EAM), Humus sólido y una fórmula química. En el experimento A, EAM y humus sólido fueron los mejores en rendimiento; EAM también tuvo los sólidos solubles más altos (STT). El Experimento B evaluó Vermicompost, Biol bovino (30%), Humus líquido con y sin micorrizas aplicado cada dos meses. Vermicompost más micorrizas tuvo un mejor desarrollo de la planta a los 60 días después del trasplante, pero no hubo diferencias estadísticas posteriormente. En este experimento, en la primera cosecha, el rendimiento fue mejor para Biol enriquecido con micorrizas seguido de Vermicompost con micorrizas. El Experimento C evaluó Biol bovino a diferentes dosis (20%, 30% y 40%) y frecuencias de aplicación (a intervalos de 10 y 20 días). En el experimento C, el Biol en dosis medias aplicado cada 10 días presentó el mayor peso de frutos. La comparación entre experimentos mostró que las plantas fertilizadas con el químico (A5) tuvieron un mejor desarrollo vegetativo en comparación con los otros experimentos. Entre la fertilización orgánica, el Biol (C1-C6) tuvo mejor desarrollo vegetal. Los mejores rendimientos tempranos fueron para Humus Sólido y para EAM aplicados mensualmente y fueron superiores a la fertilización química. El mayor peso de frutos fue con Micorrizas (A2). Los mejores TSS fueron con Biol (C1-C6) en un rango de 10,75-12,50

***Palabras clave**: Humus, micorrizas, EMAS, Biol y Vermicompost*

Abstract

This research lasted ten months; six months were for plant development and four months for harvest, the experimental units were 10 m long beds with 40 plants, the distance between plants was 40 cm. Three experiments were accomplished simultaneously in the same site. Experiment A evaluated five treatments applied monthly; four organic and a chemical (control), they were vermicompost, mycorrhizae, Efficient autochthonous microorganisms (EAM), solid humus and a chemical formula. In experiment A, EAM and solid humus were best in yield; EAM also had the highest soluble solids (STT). Experiment B evaluated vermicompost, bovine biol (30%), liquid humus with and without mycorrhizae applied every two months. Vermicompost plus mycorrhizae had better plant development at 60 days after transplant, but no statistical differences afterwards. In this experiment, at the first harvest, yield was best for biol enriched with mycorrhizae followed by vermicompost with mycorrhizae. Experiment C evaluated bovine biol at different doses (20%, 30% and 40%), and frequencies of application (at 10 and 20 days' intervals). In experiment C, biol at medium doses applied every 10 days showed the highest fruit weight. The comparison among experiments showed that plants fertilized with chemical (A5) had better vegetative development compared with the other experiments. Among the organic fertilization, biol (C1-C6) had better plant development. The best early yields were for Solid humus and for EAM applied monthly and they were higher that chemical fertilization. The best fruit weight was with Mycorrhizae (A2). Best TSS were with Biol (C1-C6) in a range of 10.75-12.50.

***Keywords:** Humus, Mycorrizae, EAM and Vermicompost*

1 Introduction

This research compared organic alternatives of fertilization in strawberry; to reach the goal of achieving ecosystems that can be sustainable from a social, ecological and economic point of view. It describes and compares three simultaneous experiments in Ecuador. The experiments investigated the effects of edaphic bio-fertilizers on growth, crop yield, and fruit quality (*Fragaria × ananassa*, cv. Albion).

Strawberries are rich in antioxidants and plant components that enhance cardiac health and regulate blood sugar (Mustafa, Petropoulos and Elsayed, 2021). The plant growth, yield and quality of strawberries, depend on the different agricultural treatments practiced during the growing season. Strawberry plants need large amounts of fertilizers, due to their high total biomass production despite the small size of the plant. Strawberries are one of the most susceptible plants in nutrients related disorders, and nutrient management is a key factor in ensuring a high yield and fruit quality. Therefore, to obtain a uniform high yield of good quality fruit, it is essential to provide adequate nutrients for plant nourishment. Nowadays, organic products are becoming more famous around the world. Many studies indicated that applying compost manure to strawberry fields may play an important role in soil amendment, improving plant nutrition, and enhancing plant growth. Intensive farming practices that result in high yield and quality also require extensive use of chemical fertilizers, which are costly and create environmental problems.

Bio-fertilizers help to accomplish the different physiological metabolic functions in plants, as the development of roots, stems, leaves, flowers and fruits, increasing photosynthesis and reducing different damages from climatic factors, as well as improving the nutritional status and maintaining a hormonal balance, facilitating the biological synthesis of auxins, gibberellins and cytokines. (Lozada, 2017). Bio stimulants could reduce the use of chemical fertilizers in strawberry, contributing to agroecosystem sustainability.

A research made in the region by Yandun in 2019, compared the effect of chemical (ammonium nitrate) and organic (Compost and bocashi) fertilization with different types of mulch (plastic and rice husk) in two varieties (Albion and Monterrey). Weekly harvests were made for three months and gave as a result that the best conditions were Albion variety, husk padding and bocashi fertilization. In her research, organic fertilization had higher fruit production than chemical.

In the province of Carchi, the most cultivated product is the potato followed by peas, barley and beans, among others. With potato, there has been people who lose money due to its price instability and the large amount of chemical products it requires. Additionally, with the practice of cultivation of the same crop over and over, the soil is degraded, and can be turned in infertile areas. Strawberry is a crop that can be adapted to the region due to its climate, and is therefore considered an alternative for profitable growing, as it is very attractive in local, national and international markets. Although in the region, it is grown only in small family gardens for self-consumption, and not for generating a quality product, capable of being exported. Within the province of Carchi, the soils are rich in nutrients, thus it is an ideal place for a great diversity of crops, among them strawberry cultivation can be an alternative. (Rivadeneira, 2016)

According to Saygi (2022), in the agricultural production process, the environmental costs of chemical fertilizers used to increase yield and quality are important issues. The main purpose of using herbal and animal wastes as an alternative to chemical fertilizers is to reduce production costs and to ensure sustainability in agricultural production by reintroducing these wastes to the economy. In his study, the effects of vermicompost, chicken manure, farm manure, and chemical fertilizers on product yield and quality, plant nutrients, and economic profitability in strawberry cultivation were investigated. His results showed that organic fertilizers gave better results than chemical fertilizers; vermicompost and chicken manure were best in yield, total sugar and nitrate accumulation in fruit; and chicken manure in vitamin C.

In India, the effect of four fermented organic matter sources (cattle, poultry and sheep manure in addition to 1:1:1 mixture of the three organic matter sources) in which 4 kg organic matter/m^2 were used and compared with conventional fertilizer (chemical fertilizers) and a control (no chemical nor organic fertilizers used) on strawberry cultivar Camaroza. The results indicated that strawberry fruit produced conventionally had higher size and moisture content than the control and organically produced fruit. The organic source treatments produced fruit with better color, higher dry matter, total phenols, crude fiber and carotene contents as compared to those produced by the control or conventional treatments. Also the organic source treatments produced fruit with higher total soluble solids (TSS) percentage and ascorbic acid content than with the conventional or the control treatments. In most cases, best results were obtained from the mixture and/or sheep organic matter source treatments (Abu-Sahra and Tahboub, 2009).

Kilic, Turemis and Dasgan (2021), investigated the effects of different organic fertilizer applications on yield and quality of organically grown Albion strawberry variety. The scope of the study covers the use of vermicompost, farm manure and humic-fulvic acid as fertilizer. The yield per plant (g/plant), fruit weight (g), pH in juice, water-soluble-solids/acid ratio in juice, plant leaf area and plant nutrition were investigated. They found that vermicompost fertilizer seems promising in organically grown strawberries nutrition.

2 Experimental section

2.1 Materials

The experiment was under open field conditions in "San Francisco Experimental Center" of Polytechnic of Carchi University, located in Huaca-Carchi-Ecuador. It is located at the latitude N: 861310, longitude W: 10068437 and 2820 meters above sea level. The dimensions of the experimental units were 0.60 m wide by 10 m long, the paths between beds were 0.50 m and the lateral paths and division were of 1 m. Each experimental unit had 40 plants with a planting distance of 40 cm.

2.2 Methods

Description of Experiment A. The area covered was 442 m^2, with 1000 plants as total. There were five treatments and five repetitions in a BCA experimental design. Four organic fertilizers and a chemical were applied to the soil. A1 was vermicompost; 125 g per plant was applied monthly for 10 months; A2 was Mycorrhizae, the fertilization was carried out twice, at the transplant and at the beginning of flowering, placing 10 grams per plant. A3 was solid humus, the fertilization was monthly placing 30 gr per plant. A4 was Efficient autochthonous microorganisms (EAM) that were applied once a month, since it is a liquid input, it must be mixed with water, in this case, one liter of EAM was applied to 4 liters of water, corresponding to 5 ml per plant. A5 is chemical, in this case it was applied 0.17 grams per month of 10-30-10 for helping the rooting, this was changed later to 10- 20-20 for stem thickening and flowering.

Description of Experiment B. The experiment covered an area of 414 m^2 with 960 plants. There were six treatments and four repetitions. Two factors were evaluated: The first factor was fertilizer with three organic alternatives: vermicompost, biol and liquid humus, the last two were applied to the plant and soil; and the second factor was Mycorrhizae (with and without its application) in a 3×2 factorial arrangement in a design BCA. The treatments were applied every two months for 10 months; B1 was vermicompost; 250 g per plant, B2 was Biol, and B3 was liquid humus, for these two treatments the fertilization was every two months placing 18.5 ml per plant at a concentration of 30%. B4 was vermicompost plus mycorrhizae, B5 was bovine biol (30%) plus mycorrhizae and B6 was liquid humus (30%) plus mycorrhizae.

Description of Experiment C. The experiment had the same dimensions of experiment B with 960 plants There were six treatments and four repetitions in a BCA experimental design. Two factors were evaluated: The first factor was bovine biol at three doses (20, 30 y 40%), applied to the soil; and the second factor was frequency (at 10 and 20 days intervals) in a 3×2 factorial arrangement in a design BCA. The biol was made from organic waste generated on the farm, that was introduced into a system with bacteria, stored in a biodigester tank, which transformed the waste into liquid-clean-high quality fertilizer.

2.2.1. The response variables

Plant height and canopy. They were measured at 60, 75 and 90 days after transplanting, taking samples of 8 plants from each experimental unit.

Yield. The harvests were once a week and the fruits of each respective experimental unit were collected and weighted, in every repetition of each treatment. The harvest began the sixth month after transplanting. Only the first four months of harvest are presented.

Dimensions of the fruits: A random sample of fruits from each experimental plot was collected the four month of harvest; to determine the average fruit weight (g), length, and diameter (cm) using a Vernier caliper.

Total soluble solids. In the juice of these same fruits, the TSS content was determined with the AOAC method (1990), using a hand refractometer and the values were reported as percentages.

pH measurement. It was performed to determine how the treatments affected the level of acidity of the fruits.

Statistical analysis. An analysis of variance (ANOVA) was made with statistical software. Tukey's test was used to compare the significant means among the different treatments at a P-value of ≤ 0.05.

3 Results and discussion

3.1 Results of each experiment

For Experiment A: Table 1 shows that statistically there were no statistical differences between treatments, in plant height nor canopy. For this, they do not have different letters in Tukey test. This means that all organic fertilizers could replace the chemical, with an adequate plant development; and in turn contributing to the environment by fertilizing with alternatives which are friendly with the environment.

Table 4 shows the yield in the first four months of harvest, in the first month is less than1 kg in all treatments (average of five repetitions from experimental units of 40 plants), and has high coefficient of variation from ANOVA (34.34%). At the 4th month produced an average of 9.63 kg with low coefficient of variation (8.34%). It can be observed, at the 2nd month, that solid humus starts with the highest values as well as the chemical; the next months they do not have statistical differences in production. The total production shows that EAM (A4) and solid humus (A3) had the highest production during the first four months of harvest.

The characteristics of the fruit were compared in Table 5 and indicates that there were no statistical differences in the dimensions of the fruits or pH. EAM (A4) increased the total soluble solids in fruits, thus the strawberries were sweeter, which is a very desirable characteristic for the consumer.

For Experiment B: The results of ANOVA, showed significant interaction between the factors. Table 2 shows that at 60 days after transplanting the plants had better growth with liquid humus with 12.65 cm, followed by vermicompost plus mycorrhizae with 12.47 cm. At the other dates, there were no statistical differences between treatments, in plant height. For canopy there were no statistical differences in the three dates. Table 4 shows the yield in the first four months of harvest, in the first month is less than1 kg per treatment, and has high coefficient of variation (24.68%). At the 4th month produced an average of 7.08 kg per treatment with a coefficient of variation of 17.54%. It can be observed that biol (B5) started as the highest production, the next months they do not have differences in production. The total production shows no statistical differences among treatments during the first four months of harvest. In Table 5; no statistical differences were found in the dimensions of the fruits, TSS or pH.

For Experiment C: The results of ANOVA, showed significant interaction for the two tested factors. Table 3 shows that there were no statistical differences between treatments, in plant height nor in canopy.

Table 4 shows that in the first month the yield was 1.41 kg per treatment, and has high coefficient of variation (33.83%). At the 4th month produced an average of 6.75 kg per treatment with high coefficient of variation (19.20%). They do not have statistical differences in monthly production. The total production of four months of harvest does not show differences among treatments either.

The physical parameters of fruit (pH, TSS, weight, diameter and length) are presented in Table 5, and indicate no statistical differences in the dimensions of the fruits or TSS. When biol was applied at low rate and at a frequency of 10 days (C1), the fruits were less acid (highest pH). The heaviest fruits were at medium biol rate applied every 10 days (C2).

3.2 Comparison of plant growth among experiments

The three experiments were simultaneous but the experimental design and treatments evaluated were different thus they can only be compared in a descriptive manner as in figure 1. The treatments in the first experiment were A1-A5; in the second experiment were B1-B6 and in the third were C1-C6. The figure on top (1) was at 60 days after transplant, the middle (2) was at 75 days after transplant and the one in the bottom (3) was at 90 days after transplant.

The canopy was a better indicator of the well-being of the plant than the height. It was noticeable the differences in growth for the plants fertilized with chemical (A5), when this treatment is compared with the others experiments. Among organic fertilizers (all the other treatments except A5), it can be seen that plants fertilized with biol (C1-C6) showed better growth especially at 90 days after transplant (figure 1).

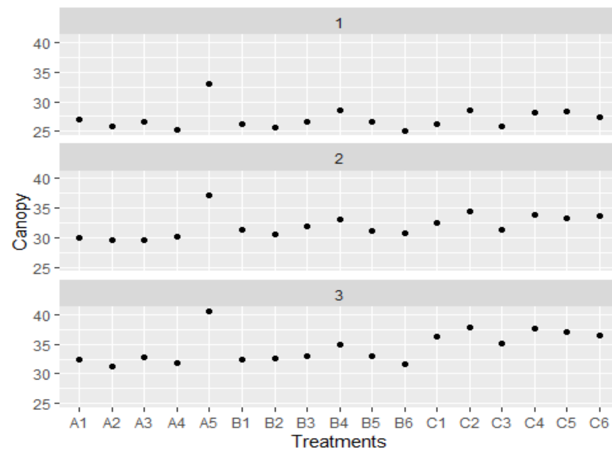

Fig 1. Plant canopy per sampling in cm at 60, 75 and 90 days after transplant. (Dosel de la planta por muestreo en cm a los 60,75 y 90 días después del trasplante**).**

Legend: A1: vermicompost; A2: Mycorrhizae; A3 was solid humus, A4: EAM; A5: chemical; B1: vermicompost; B2: Bovine biol (30%); B3: liquid humus; B4: vermicompost plus mycorrhizae, B5: bovine biol (30%) plus mycorrhizae; B6: liquid humus (30%) plus mycorrhizae; C1: Biol (20%) - 10 day; C2: Biol (30%) - 10 day; C3: Biol (40%) - 10 day; C4: Biol (20%) - 20 day; C5: Biol (30%)- 20 day; C6: Biol (40%) - 20 day.

3.3 Yield

Figure 2 shows that in the first month of harvest, at the left in the top (1), Experiment C, specially the treatments C1, C2 and C3 were slightly better than the other treatments, with yield over 1.4 Kg per experimental unit. These treatments were biol at the different doses applied every 10 days. It is normal to have low yield at the beginning of production, with plants with many flowers and few fruits. It is evident that in this phase the biol helps the plants to accelerate the production in comparison with all the other treatments.

The second month of harvest (at the top on the right (2)), shows an increased production in the first experiment (A1-A5), in particular A5 (chemical) and A3 (solid humus) were higher in comparison with all the other treatments; with an average of approximately 5 kg per experimental unit.

Fertilization that includes Mycorrhizae (A2) and EAM (A4) were second best with an average of 4.5 Kg this month. The experiment B (B1- B6) presented lower production of fruits with averages around 2.4 kg. The fertilization with vermicompost, biol and liquid humus, alone or enriched with mycorrhizae, were not as effective in production at this point.

It is important to compare the yield of A1 in which the vermicompost was 125 g per plant applied monthly and B1 which was 250 g of vermicompost applied every two months. It is the same amount of fertilizer only that A1 was applied in a fractioned manner. Thus it shows that the yield is bigger when vermicompost is applied in a fractionated form.

The third month of harvest (at the bottom- left (3)) shows and increase of production in A4 (EAM), in comparison with all the other treatments with an average of 9.4 kg per experimental unit. In general experiment A (A1-A6) had higher yield than the rest.

The fourth month of harvest (at the bottom-right (4)) shows an increase of production in all treatments of experiment A (A1-A6), in comparison with the others, with an average of 9.6 kg per experimental unit. When comparing the yield of A1 and B1, which is the same amount of vermicompost in two ways of application, it can be observed that it is better to apply vermicompost monthly instead of every two months.

Treatments in Experiment C started in the first months of production better than the others, this indicates that biol can be used to boost the production at the beginning of harvest, but the next months is better to add edaphic organic fertilizers such as the ones used in Experiment A: Vermicompost, Mycorrhizae, Solid humus or EAM applied monthly. In the fourth month the maximum production, taking into consideration all treatments, was around 250 g per plant.

3.4 Fruit characteristics

One of most valued qualities of the fruit is the diameter. In the tri-dimensional figure (figure 3); it can be observed the relation between fruit length and diameter for each treatment. The best fruit diameter was obtained by B3: liquid humus with 4.67 cm, B5: Biol at 30% plus mycorrhizae with 4.62 cm and A2: Mycorrhizae with 4.46 cm, and the least was C6: Biol at 40% applied every 20 days, with 3.92 cm of diameter. The longest fruit was again B5 with 6.27 cm, followed by B3 with 6.20 cm and the least length was C1: Biol at 20% applied every 10 days, with 5.22 cm. It was observed that B3: liquid humus and B5: Biol plus mycorrhizae produced quality fruits (longer end wider), which had better acceptance for the consumer, these two fertilizers gave as a result better fruits that the ones with chemical fertilizers (A5).

Figure 4 shows that the fruits with highest weight were fertilized with Mycorrhizae (A2) with 42.68 g. High total soluble solids (TSS) is other desirable quality in strawberry fruits. It was observed the highest SST of 12.5 in C6: Biol at 40% applied every two months; it could had happened because these fruits at the moment of harvest were ripe and the other treatments were half ripe, which is the right moment to collect them. There were no significant differences in pH for all three experiments, meaning that all fruits had about the same values with average near 3.3.

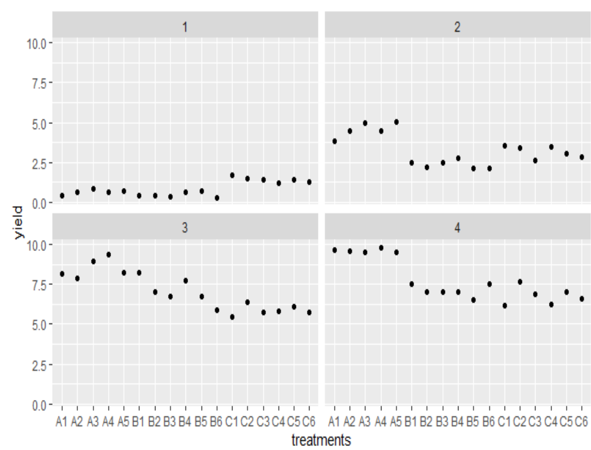

Fig. 2. Yield in kg per month during first fourth month of harvest. (Rendimiento en kg por mes durante cuatro meses de cosecha).
Legend: A1: vermicompost; A2: Mycorrhizae; A3 was solid humus, A4: EAM; A5: chemical; B1: vermicompost; B2: Bovine biol (30%); B3: liquid humus; B4: vermicompost plus mycorrhizae, B5: bovine biol (30%) plus mycorrhizae; B6: liquid humus (30%) plus mycorrhizae; C1: Biol (20%) - 10 day; C2: Biol (30%) - 10 day; C3: Biol (40%) - 10 day; C4: Biol (20%) - 20 day; C5: Biol (30%)- 20 day; C6: Biol (40%) - 20 day

The comparison among experiments showed that the plants fertilized with chemical (A5) had better vegetative development. Referring to this, Hassan in 2015, assured that treatments that received 100% of the recommended dose of inorganic fertilizers recorded higher values in all plant traits.

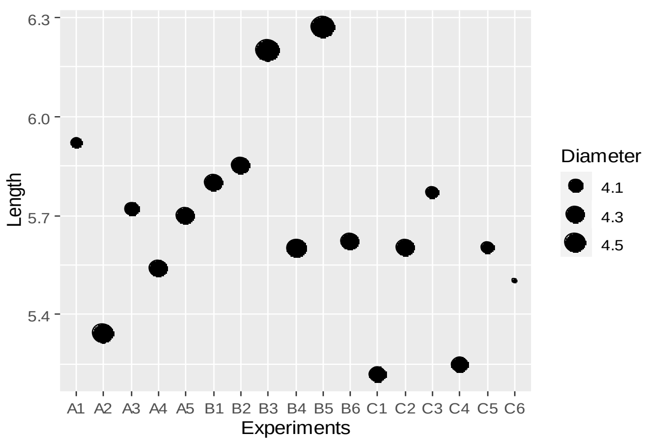

Fig. 3. Relation between fruit length and diameter. (Relación entre longitud y diámetro del fruto).
Legend: A1: vermicompost; A2: Mycorrhizae; A3 was solid humus, A4: EAM; A5: chemical; B1: vermicompost; B2: Bovine biol (30%); B3: liquid humus; B4: vermicompost plus mycorrhizae, B5: bovine biol (30%) plus mycorrhizae; B6: liquid humus (30%) plus mycorrhizae; C1: Biol (20%) - 10 day; C2: Biol (30%) - 10 day; C3: Biol (40%) - 10 day; C4: Biol (20%) - 20 day; C5: Biol (30%)- 20 day; C6: Biol (40%) - 20 day

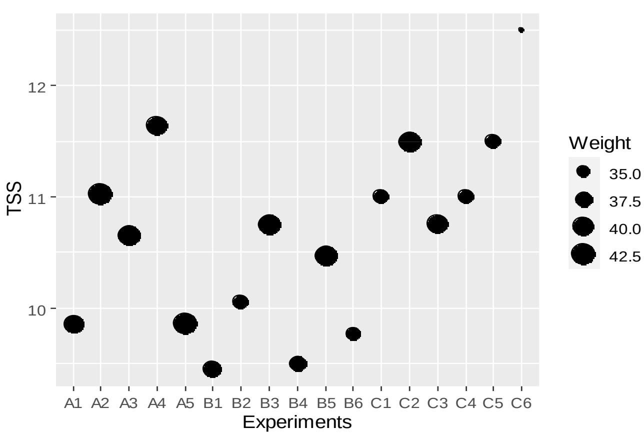

Fig. 4. Relation between TSS and fruit weight. (Relación entre TSS y peso del fruto).

Legend: A1: vermicompost; A2: Mycorrhizae; A3 was solid humus, A4: EAM; A5: chemical; B1: vermicompost; B2: Bovine biol (30%); B3: liquid humus; B4: vermicompost plus mycorrhizae, B5: bovine biol (30%) plus mycorrhizae; B6: liquid humus (30%) plus mycorrhizae; C1: Biol (20%) - 10 day; C2: Biol (30%) - 10 day; C3: Biol (40%) - 10 day; C4: Biol (20%) - 20 day; C5: Biol (30%)- 20 day; C6: Biol (40%) - 20 day

In experiment A, vermicompost at 125 g/plant applied every 10 days (2.5 Kg per plant in a 10-month period), gave excellent plant development and it is a good fertilization alternative for strawberry, since it presented good average plant height and width. In experiment B, 250 g/plant vermicompost applied to the soil every 20 days gave lower yields. It was used the same amount of vermicompost that was applied in a fractionated matter in experiment A. All the treatments in experiment A had same plant development and yield; the SST was higher with EAM than with chemical.
These results agree with Pérez *et al*. (2013), who obtained in their research good development of the plants in early days with vermicompost, due to the physical properties since it gave higher degree of porosity and microspores to the soil, which helps aeration. Vázquez and Loli (2018), had similar conclusion, they applied 1.3 kg/plant of vermicompost throughout the investigation and soil quality was improved.

In Experiment B, for the canopy at 60, 75 and 90 days from transplant, the best yield was vermicompost plus mycorrhizae (B4). It could also be observed that biol plus mycorrhizae (C5) starts as the highest production, the next months they do not have differences in production. In fruit quality, Liquid humus had the highest SST but no statistical differences with the others treatments.

Duan, Peng, Zhang, Han and Li, in China (2021) and Mora *et al* in Ecuador (2021), assured that biofertilizers contains a variety of microorganisms, which can help plants absorb nutrients and improve soil structure, thus affecting plant growth and crop quality. They consider that it is a better choice to replace part of chemical fertilizer to achieve sustainable development of agriculture. Their results showed that both FF: Foliar fertilization - Leaf inoculation (microbial inoculants in leaf) and MF: Mycorrhizal fertilization through soil inoculation (microbial inoculants in soil), with yeast as a biofertilizer, significantly increased the TSS content. Additionally, the TSS content in plants treated with MF was higher than with FF. Arbuscular Mycorrhizal Fungi can effectively increase phosphorus, sulfur and nitrogen fixation to increase crop yield and TSS.

Negi; Sajwan; Uniyal and Mishra (2021) found that the combination of biofertilizers with organic manures (especially, farm manure and vermicompost) should be used for sustainably higher production of quality strawberries especially under organic farming system. Such approaches have a higher rationale with small farm or hill agriculture systems, where farmers generally have few economic resources.

Kilic, Turemis and Dasgan (2021), indicated in a research in Adana-Turkey, with the same strawberry variety (Albion), observed that the biggest fruits were obtained with vermicompost with average weight of 18.81 g. The difference between applications was not significant for fruit juice pH values. However, the highest total soluble solids (TSS)/acid ratio was obtained with 9.82 from humic-fulvic acid application. TSS/acid ratio in strawberries is an important quality criterion in determining the taste. It is noticeable the differences in average fruit weight with our research, it must be because in the location of Ecuador where our experiments took place, conditions are quite favorable for this crop. Relating to this, Shaw and Larson (2008), reported that phenotypic characteristics can vary according to growing conditions.

Nunes *et al.* (2021), explained that the sensorial, physical-chemical and nutritional characteristics of strawberries are parameters of quality that influence the choices of consumers. However, these characteristics may be influenced by intrinsic and extrinsic factors that alter the fruit quality. The concentrations of nutrients and other chemical compounds in strawberries may increase and/or decrease according to the cropping system, maturation stage, climatic conditions, and preservation and storage methods. Factors characteristic of the cultivar, such as the genetic profile, may also influence the composition of strawberries. In this research made in Brazil with different strawberry varieties, the TSS (°Brix) went from 6.42 for Aromas to 8.92 in Tudla, those results were considerably lower than in the present experiments.

Romero-Gamez and Suárez-Rey in 2020, assured that the use of more rational farming techniques, such as those implemented in integrated crop production, can reduce environmental burdens in open field systems. The fertilizers stage acquired the most importance in most of the environmental categories and cropping systems, followed by the stages of pesticides and auxiliary equipment. Acidification, eutrophication, and ecotoxicity were the categories with the highest impacts in all the strawberry production systems. In order to improve the environmental performance of strawberry production, the optimization on the use of fertilizers, for example, the use of decision support systems on nutrient management and provisions for training programs for farmers, should be considered on this highly sensitive area. In addition, the use of recycled materials and/or with longer service life and the use of renewable energy could be effective in decreasing the environmental impacts.

Table 1. Tukey´s Test for Plant Height and Width at three dates after transplant - Experiment A (Prueba de comparaciones múltiples de Tukey para Altura y Dosel de la planta a tres fechas después del trasplante. Experimento A)

	Height (cm)		
Treatment	60 d	75 d	90 d
A1. WormC (30 days)	19.69	20.55	21.95
A2. Mycorrhizae	18.90	20.95	22.02
A3. Solid humus	20.01	21.18	22.68
A4. EAM	19.23	21.55	21.68
A5. Chemical	19.23	21.40	23.12
General Mean (cm)	19.41	21.12	22.28
CV (%)	9.69	7.03	4.99
	Width of canopy (cm)		
	60 d	75 d	90 d
A1. WormC (30 days)	26.99	30.04	32.49
A2. Mycorrhizae	25.84	29.64	31.19
A3. Solid humus	26.67	29.68	32.88
A4. EAM	25.35	30.15	31.92
A5. Chemical	32.92	37.20	40.41
General Mean (cm)	26.41	30.06	32.43
CV (%)	7.98	7.50	6.40

Note: Only the means with statistical differences in Tukey test were identified with different letters

Table 2. Tukey´s Test for Plant Height and Width at three dates after transplant - Experiment B (Prueba de comparaciones múltiples de Tukey para Altura y Dosel de la planta a tres fechas después del trasplante. Experimento B)

	Height (cm)		
Treatment	60 d	75 d	90 d
B1. WormC (60 days)	12.18 AB	14.53	15.75
B2. Biol	12.09 AB	14.18	15.47
B3. Liquid Humus	12.65 A	14.22	15.65
B4. WormC+Mycorrhizae	12.47 AB	14.37	15.47
B5. Biol+Mycorrhizae	12.28 AB	14.69	15.96
B6. Humus+Mycorrhizae	11.34 B	14.25	14.84
General Mean (cm)	12.17	14.37	15.53
CV (%)	14.54	13.26	12.83
	Width of canopy (cm)		
	60 d	75 d	90 d
B1. WormC (60 days)	26.99	30.04	32.49
B2. Biol	25.84	29.64	31.19
B3. Liquid Humus	26.67	29.68	32.88
B4. WormC+Mycorrhizae	25.35	30.15	31.92
B5. Biol+Mycorrhizae	32.92	37.20	40.41
B6. Humus+Mycorrhizae			
General Mean (cm)	26.41	30.06	32.43
CV (%)	7.98	7.50	6.40

Note: Only the means with statistical differences in Tukey test were identified with different letters

Table 3. Tukey´s Test for Plant Height and Width at three dates after transplant - Experiment C (Prueba de comparaciones múltiples de Tukey para Altura y Dosel de la planta a tres fechas después del trasplante. Experimento C)

	Height (cm)		
Treatment	60 d	75 d	90 d
C1. Biol L - 10 day	15.00	18.63	20.75
C2. Biol M - 10 day	17.03	19.31	21.43
C3. Biol H - 10 day	16.34	19.63	21.68
C4. Biol L - 20 day	17.28	20.34	22.03
C5. Biol M - 20 day	16.72	18.84	22.31
C6. Biol H - 20 day	15.59	19.12	21.37
General Mean (kg)	16.33	19.48	21.60
CV(%)	15.54	8.71	8.67
	Width of canopy (cm)		
Treatment	60 d	75 d	90 d
C1. Biol L - 10 day	26.25	32.50	36.25
C2. Biol M - 10 day	28.65	34.50	37.84
C3. Biol H - 10 day	25.87	31.31	35.16
C4. Biol L - 20 day	28.25	33.91	37.56
C5. Biol M - 20 day	28.37	33.37	37.03
C6. Biol H - 20 day	27.47	33.59	36.46
General Mean (kg)	27.48	33.19	36.72
CV(%)	12.40	5.95	4.13

Table 4. Tukey´s test for yield in the first four months of harvesting (kg). (Prueba de comparaciones múltiples de Tukey en los cuatro primeros meses de cosecha en kg)

EXP A	Month				
Treatment	1st	2nd	3rd	4th	Total
A1	0.42 B	3.82 B	8.14	9.67	22.06 B
A2	0.63 AB	4.49 AB	7.85	9.60	22.59 AB
A3	0.82 A	4.97 A	8.91	9.54	24.25 A
A4	0.63 AB	4.48 AB	9.40	9.80	24.33 A
A5	0.68 AB	5.02 A	8.25	9.53	23.50 AB
GM(kg)	0.64	4.56	8.51	9.63	23.35
CV (%)	34.34	11.90	10.85	8.34	5.37
EXP B	Month				
Treatment	1st	2nd	3rd	4th	Total
B1	0.44 ABC	2.46	8.25	7.50	18.66
B2	0.40 BC	2.21	7.00	7.00	16.62
B3	0.34 C	2.47	6.75	7.00	16.55
B4	0.63 AB	2.78	7.75	7.00	18.15
B5	0.70 A	2.15	6.71	6.50	16.07
B6	0.31 C	2.13	5.91	7.50	15.86
GM(kg)	0.47	2.37	7.06	7.08	16.98
CV (%)	24.68	23.70	17.39	17.54	13.84
EXP C	Month				
Treatment	1st	2nd	3rd	4th	Total
C1	1.72	3.54	5.45	6.18	16.89
C2	1.48	3.39	6.40	7.63	18.91
C3	1.42	2.63	5.77	6.89	17.01
C4	1.19	3.47	5.79	6.22	16.66
C5	1.41	3.08	6.10	7.03	17.62
C6	1.26	2.87	5.74	6.58	16.45
GM(kg)	1.41	3.22	5.87	6.75	17.26
CV (%)	33.83	19.58	13.16	19.20	12.58

Note: Only the means with statistical differences in Tukey test were identified with different letters

Table 5. Tukey´s test for fruit quality (Prueba de comparaciones múltiples de Tukey para calidad de fruto)

EXPA					
Trt	pH	TSS	W (g)	Diam (cm)	Length (cm)
A1	3.36	9.86 B	39.39	4.04	5.92
A2	3.28	11.02 AB	42.68	4.46	5.34
A3	3.28	10.66 AB	40.85	4.12	5.72
A4	3.44	11.64 A	39.67	4.32	5.54
A5	3.28	9.86 B	42.18	4.30	5.70
GM	3.32	10.68	40.95	4.25	5.64
CV(%)	4.23	6.85	13.29	8.08	7.07
EXP B					
B1	3.45	9.45	37.55	4.27	5.80
B2	3.42	10.05	36.54	4.32	5.85
B3	3.35	10.75	41.85	4.67	6.20
B4	3.32	9.50	37.24	4.37	5.60
B5	3.40	10.47	41.71	4.62	6,27
B6	3.37	9.77	35.56	4.27	5.62
GM	3.38	10,00	38.41	4.42	5.89
CV (%)	2.62	11.03	13.18	7.11	8.51
EXPC					
C1	3.50 A	11.00	35.98 AB	4.22	5.22
C2	3.28 AB	11.50	41.44 A	4.27	5.60
C3	3.40 AB	10.75	40.36 AB	4.05	5.77
C4	3.35 AB	11.00	36.52 AB	4.22	5.25
C5	3.33 AB	11.50	36.59 AB	4.07	5.60
C6	3.22 B	12.50	33.03 B	3.92	5.50
GM	3.35	11.54	37.32	4.13	5.49
CV (%)	5.61	13.04	16.04	10.49	6.79

Note: Only the means with statistical differences in Tukey test were identified with different letters

4 Conclusions

- ✓ All organic inputs had an adequate plant development; thus the plants with chemical fertilizers showed better growth. Biol fertilized plants had improved plant growth than the other organic fertilized plants.

- ✓ The highest yield was for solid humus and EAM with average in the accumulated production of four months around 24 kg, all fertilizers in Experiment A can replace the chemical with an adequate plant growth and high yield, and in turn contributing to the environment by fertilizing with organic alternatives which are environment friendly.

- ✓ The best fruit diameters were found in B3: liquid humus with 4.67 cm, B5: Biol at 30% plus mycorrhizae with 4.62 cm and A2: Mycorrhizae with 4.46 cm in diameter. It was observed that B3 and B5 produced quality fruits which had higher prices in the market, even better that the ones with chemical fertilizers (A5). Moreover, applying organic fertilizers and biofertilizers could improve soil physicochemical parameters in the long term, which is very important in practicing sustainable cropping systems and reducing chemical inputs in the production chain

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García Bolívar, Judith Josefina. *Ingeniera Agrícola, Magíster en Ciencias por la Universidad del Estado de Kansas, PhD en Ciencias Agrícolas de la Universidad Central de Venezuela. Correo electrónico: garciaj66@gmail.com*
https://orcid.org/0000-0003-0254-3626

Riofrio Fuelagan, Edison Andrés: *Ingeniero Agropecuario de la Universidad Politécnica del Carchi. Correo electrónico: andres11riofrio@gmail.com*
https://orcid.org/0009-0005-4688-749X