Article

Impact of organic fertilizers associated with mycorrhizae on yield and nutraceutical quality of cucumber

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Abstract

The use of organic fertilizers together with arbuscular mycorrhizal fungi (AMF) are an alternative for the recovery of soils and optimizing the quality of foods because they help improve the absorption of nutrients that leads to obtaining foods free of agrochemicals. Therefore, the objective of the study was to evaluate the effect of organic fertilizers and AMF on the dynamics of cucumber production and quality. The study was conducted at UAAAN-UL, Torreón, Coahuila, during 2019. Six treatments were generated: AEBE= sand + bovine manure + Ecomic; AECE= sand + goat manure + Ecomic; AEEE= sand + equine manure + Ecomic; SEEE= soil + equine manure + Ecomic; ACE= sand + compost + Ecomic; and ASNS= sand + Steiner nutrient solution. The treatments were established in a completely randomized design with six repetitions. The following variables were evaluated: plant height, stem diameter, length, width and weight of fruit, yield, firmness, soluble solids, phenolic compounds, flavonoids and antioxidants. The data obtained were subjected to an analysis of variance and Tukey tests ($p \leq 0.05$). The results showed significant differences in all the variables analyzed and the AEBE treatment stood out in plant height, weight and fruit diameter, while all treatments with organic fertilization obtained better response in nutraceutical quality, compared to the control.

Keywords: antioxidants, organic fertilization, substrates.

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Introduction

At present, the impact of climate change, soil degradation, the high cost of synthetic fertilizers and the demand to produce safe foods with high nutritional value, improving agricultural productivity and quality is vital to raise the global standard of living and promote sustainable food production in the face of growing challenges for agriculture (Ortiz-Bobea *et al*., 2021). Organic fertilization is an alternative for the recovery of soils and improving the quality of foods because it provides the necessary amounts of nutrients to plants, collaborates with the production of stimulants for plant growth, improves soil stability and collaborates with the biodegradation of substances (Peñaloza-Monroy *et al*., 2019), also, the use of biofertilizers favors improving socioeconomic, ecological conditions, and the preservation of the environment (Chew *et al*., 2019).

One of the measures to complement the benefits of the use of organic fertilizers is the integration of beneficial microorganisms of the soil and among the most important are AMF (Xiao *et al*., 2020), which colonize 90% of the plant species. AMF help increase plant water and nutrient exchange and therefore have positive effects on plant growth and nutrition, especially in phosphorus-deficient soils (Tedersoo *et al*., 2020), in addition, they significantly increase crop yields while reducing the quantity of synthetic fertilizers and improving crop resistance to insects (Wang *et al*., 2020; Krzyzaniak *et al*., 2021).

Plants and AMF have developed strategies to obtain nutrients from soils, which occurs through the colonization of roots by AMF and creates a nutrient absorption pathway, in addition to the direct absorption pathway through the root hairs. Therefore, the use of these microorganisms is an alternative to improve crop nutrition, especially in subsistence or low-input agricultural systems (Comby *et al*., 2017). At present, organic fertilizers and AMF represent an alternative to maintain the sustainability of agricultural crops, therefore, it is necessary to continue with the studies of the relationship between the two, mainly to know the response in the quality of fruit, because it is known that the use of organic fertilizers helps improve the flavor and aroma (Ma *et al*., 2020).

In previous studies, the response to the use of organic fertilizers together with mycorrhizae has been positive. In this sense, Jiménez Ortiz *et al*. (2019) obtained a significant response in forage maize yield using manure compost as a substrate in interaction with mycorrhizae. Likewise, Cos *et al*. (2013) showed that the treatment *Glomus cubense* + worm humus obtained an average yield of 73.47 t ha^{-1} of tomato production. Therefore, it has been shown that the use of organic fertilizers associated with the use of arbuscular mycorrhizae are a good alternative as biofertilizers, reducing with them the problems of soil degradation, nutrients for plants and in short more friendly to the environment, however, there are few studies on the effect of organic fertilizers and AMF on the yield and nutraceutical quality of cucumber. Therefore, the objective of the work was to evaluate the effect of organic fertilizers associated with AMF on the yield and nutraceutical quality of cucumber.

Materials and methods

Description of the study area

The study was carried out in spring-summer 2019, in the greenhouse area of the Antonio Narro Autonomous Agrarian University, Laguna Unit (UAAAN-UL), for its acronym in Spanish), which is in the municipality of Torreón, Coahuila, Mexico, at 25° 33' 26" north latitude and 103° 22' 21" west longitude, at an altitude of 1 120 masl.

Description of treatments

The treatments were substrates obtained by mixing manure from equine (EE), goat (EC), bovine cattle (EB), compost, soil and sand. The substrate mixtures were formulated based on volume, then passed through a number five sieve to have homogeneous substrates and then sterilized in a bain-marie for four hours. The treatments consisted of five different substrates added with mycorrhizae and a control that was sand irrigated with nutrient solution (Table 1).

Table 1. Description of the treatments obtained based on the different types of substrates.

Treatment	Composition of treatments
AEBE	River sand (75%) + bovine manure (25%) + Ecomic®
AECE	River sand (75%) + goat manure (25%) + Ecomic®
AEEE	River sand (50%) + equine manure (50%) + Ecomic®
SEE	Sterilized soil (100%) + Ecomic®
ACE	River sand (75%) + compost (25%) + Ecomic®
ASNS	River sand (100%) + Steiner nutrient solution

Before sowing, the treatments were washed with water for five days, with the aim of decreasing the concentration of salts in the substrates. Subsequently, at the time of sowing, commercial biofertilizer ECOMIC® was added, which is composed of spores of different species of AMF, mainly *Glomus geosporum*, *G. fasciculatum*, *G. costrictum*, *G. tortuosum*, *Gigaspora margarita* and *Acaulospora* sp. For irrigation water, pH and electrical conductivity (EC) analyses were performed.

The pH was analyzed using a digital potentiometer (Hanna Instruments Hl 98107®), while the EC was measured using the conductivity meter method, according to the official Mexican standard NOM.021-RECNAT-200 (SEMARNAT, 2014). The mean values obtained were 8.4 for pH and 1.9 dS cm^{-1} for EC. In order to carry out the irrigation, citric acid was applied at a concentration of 1 g L^{-1} of water to lower the pH to a final concentration of 5.5. Likewise, before sowing, physicochemical analyses of the different substrates obtained were carried out (Table 2).

Table 2. Physicochemical characteristics of the five types of substrates.

Substrates	Texture	pH	EC	OM	N	P	Mg	Ca	Cl	SO_4	CO_3	HCO_3
			(dS cm^{-1})	(%)		(mg kg^{-1})				(meq L^{-1})		
AEB	C-S	7.8	6.94	1.88	1.67	48.6	116.64	162.32	39.2	189	3.8	16.4
AEC	C-L	7.7	6	1.44	1.67	97.31	182.25	272.54	32	171	3.2	11.2
AEE	C-L	7.7	4.07	1.15	1.6	29.04	92.34	132.26	15.6	151.5	4.2	9.6
SE	C-L	8	8.89	1.27	1.58	232.29	131.22	166.33	49.6	130.78	5.2	16
AC	C-S	7.3	5.34	1.33	1.6	17.65	182.25	280.56	23.8	139.5	1.6	6.2

AEB= river sand + bovine manure; AEC= river sand + goat manure; AEE= river sand + equine manure; SE= sterilized soil; AC= river sand + compost; CS= clayey sand; CL= clayey loam; EC= electrical conductivity; OM= organic matter.

Establishment of the crop

The sowing was carried out on May 12, 2019, under a greenhouse system of 200 m^2 of metal structure, polyethylene cover with thickness 0.7 mm and an anti-aphid mesh, with two side windows and two fans. The sowing was carried out in black polyethylene bags with a capacity of 15 kg and cucumber seeds of the Poinsett® hybrid were used as plant material. To have uniform plants, the sowing was carried out directly, placing two seeds per pot and when the seedlings had two true leaves, one was removed, to have a density of four plants per square meter. When sowing, 100 g of the biofertilizer was added along with the seeds. The irrigation was carried out manually, applying 500 ml of water per day and it was increasing according to the crop cycle, until watering a maximum of two liters per day in the production stage. Natural water for the five treatments with mycorrhizae, and the control (ASS) with Steiner nutrient solution.

Variables evaluated

Plant height and stem diameter were evaluated from eight days after sowing (das), while the harvest was carried out from 65 das, and the physical properties of the fruit were measured: length, polar diameter, firmness, weight and yield per plant. Subsequently, the quality of the fruit was determined by means of the variables: soluble solids, antioxidant capacity, total phenols and flavonoids. At the end of the harvest, the percentage of colonization of mycorrhizae was determined.

Plant height and yield

Measurements of plant height and stem diameter were made from the formation of the first true leaves, and they were measured once a week until 82 das. Plant height was measured with a tape measure, measuring the plant at ground level to the apex of growth, while the stem diameter was measured with a Stainless Hardened® vernier on top of the first mature leaf.

The harvest of fruits was carried out from 65 das, before reaching their commercial maturity, considering the characteristics of the change of color from green to dark, rounded apical end of the fruit, the grooves are less pronounced, the external firmness and brightness indicate desired premature state. In total, four cuts were made, where the yield was evaluated by counting the number of fruits harvested and the weight of the fruits per plant (kg). As for the measurement of the length and polar diameter of the fruit, it was made with a Stainless Hardened® vernier, while the firmness was measured with the help of a penetrometer (Fruit Hardness Tester FHT200) and the total soluble solids (°Brix) were quantified in fresh fruit with a digital refractometer (CIVEQ® model CVQ-4012).

Extraction and quantification of total phenols, flavonoids and antioxidant capacity

Acetone at 80% was used as an extraction solvent. One hundred milligrams of fresh sample were weighed and 1.5 ml of acetone was added, then it was stirred for 2 min in a vortex and then centrifuged at 10 000 rpm for 15 min, the supernatant was recovered, the pellet was added 500 µl of 100% acetone, it was stirred again in a vortex for 2 min and centrifuged at 10 000 rpm for 15 min, the supernatant was recovered and mixed with the previous one, the same procedure was repeated until 2 ml was completed, which was stored at 4 °C in darkness for the quantification of total phenols, flavonoids and antioxidant capacity.

Quantification of total phenols

The total phenol content was determined colorimetrically by the Folin-Ciocalteu method (Singleton *et al*., 1999). For the quantification, a mixture of the extract obtained and the reagents of the original technique (0.5 ml of Folin-Ciocalteu, deionized water 7.5 ml, 1.5 ml of sodium carbonate (Na_2CO_3)) was made. For the reaction, 200 µl of the extract, 100 µl of the Folin-Ciocalteu 1M reagent, 200 µl of 20% Na_2CO_3 and 1.5 ml of distilled water were placed, before the reading of the samples, they were incubated for 30 min in darkness and then the absorbance was measured at 765 nm in a Genesys 10S UV-Vis® spectrophotometer. The results were expressed as milligrams of gallic acid equivalents per 100 g of fresh weight of sample (mg GAE 100 g^{-1} fw).

Flavonoid content

The total flavonoid content was determined by the method proposed by Barros *et al*. (2010), which is based on the formation of a flavonoid-aluminum complex. A mixture of 500 µl of the extract, 200 µl of distilled water and 150 µl of 5% sodium nitrate (w/v) was made, stirred and left to stand for 6 min, then 150 µl of 10% aluminum chloride (w/v) was added, it was stirred again and left to stand for 6 min and finally 2 000 µl of 4% sodium hydroxide and 200 µl of distilled water were added to the mixture, it was stirred and left to stand for 15 min, then absorbance was measured at 415 nm on a spectrophotometer. The total flavonoid content was determined by a calibration curve with quercetin for concentrations of 200 to 400 mg L^{-1}. The results were expressed in milligrams of quercetin equivalents per 100 g of fresh weight (mg QE 100 g^{-1} fw).

Antioxidant capacity

The antioxidant capacity was determined by the method of Brand-Williams *et al*. (1995), by means of the free radical capture capacity 1,1-diphenyl-2-picryl-hydrazyl (DPPH). For the determination of the antioxidant capacity, in Eppendorf tubes, 200 µl of the previously obtained ketone extract and 2 ml of the DPPH solution at 0.1 M were mixed, stirred in the vortex for three minutes and the sample obtained was incubated for 1 h, after this time, it was stirred in the vortex for three seconds and read at an absorbance of 515 nm in a Genesys 10S UV-Vis® spectrophotometer. All measurements were made in triplicate. The antioxidant capacity was determined by a calibration curve based on Trolox diluted in absolute ethanol. The results were expressed in milligrams of Trolox equivalents per 100 g of fresh weight (mg TE 100 g^{-1} fw).

Percentage of colonization

The roots of plant separated in each of the samples were placed in plastic capsules, wrapping them in thin fabric, to prevent the loss of thinner roots. Subsequently, the capsules were incubated in a 10% KOH solution for 12 h, after this time, the roots were washed three times with deionized water, immediately transferred to a 10% H_2O_2 solution for 10 min and two washes were carried out with water and they were placed in a 10% HCl solution for five minutes. After this time, the samples were placed in a solution of trypan blue for three minutes and were placed in a pressure cooker to take 10 lb in^{-2} (psi) for 10 min, subsequently, a water wash was performed and the capsules with the roots were cooled at ±4 °C temperature until their observation under the microscope (Phillips and Hayman, 1970).

The roots were cut into sections 1 cm long, placed on slides and subsequently a drop of Lacto-glycerol solution was applied for their observation under the microscope. Colonization was based on the presence of the percentage of fungal structures within the root and was performed in triplicate in each treatment (Parra-Rivero *et al*., 2018). The percentage of colonization was obtained by the following formula: $\text{total colonization (\%)} = \frac{\text{colonized segments}}{\text{non-colonized segments + colonized segments}} *100$. $\text{Arbuscules (\%)} = \frac{\text{segments with arbuscules}}{\text{total segments}} *100$. $\text{Vesicles (\%)} = \frac{\text{segments with vesicles}}{\text{total segments}} *100$. $\text{Hyphae (\%)} = \frac{\text{segments with hyphae}}{\text{total segments}} *100$.

Experimental design and statistical analysis

All data obtained were subjected to an analysis of variance under a completely randomized design with six treatments and seven repetitions. The probability of significance was used to compare the treatments with the Tukey test $p \leq 0.05$, using the statistical program SAS (SAS, 2009).

Results and discussion

Effect of organic substrates and mycorrhizae on the growth of cucumber plants

The growth curves for the variable plant height show a better response of the treatments AEBE, ACE and AEEE (Figure 1a); however, the ASNS treatment (control) obtained a slow growth during the first 40 das and subsequently the trend improved. On the other hand, the treatment of sterilized soil with mycorrhizae (SEE) was the one that had a slower growth and with small plants with respect to the rest. It is observed that, in treatments with organic fertilizers combined with AMF, they have a greater effect on the growth of the plant.

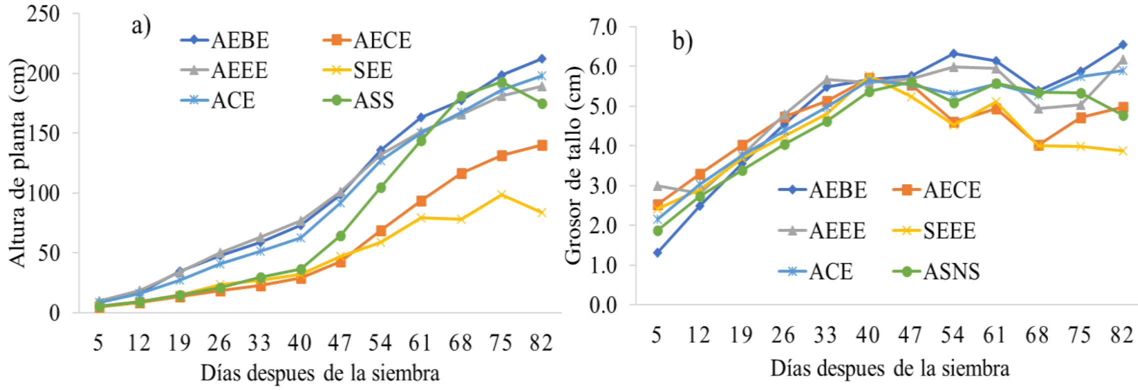

Figure 1. Plant height and stem thickness of cucumber in organic substrates with mycorrhizae. Means with different letters mean statistical differences ($p \leq 0.05$) between treatments. AEBE= sand + bovine manure + Ecomic; AECE= sand + goat manure + Ecomic; AEEE= sand + equine manure + Ecomic; SEEE= soil + equine manure + Ecomic; ACE= sand + compost + Ecomic; ASNS= sand + Steiner nutrient solution.

This fact can be attributed to the rich mineral content provided by organic substrates, along with the positive effect of mycorrhizae on nutrient absorption, and they are manifested in increased plant growth that can guarantee greater biological and agronomic productivity (Alvarado-Carrillo *et al*., 2018; Elliot *et al*., 2020), in addition to this, manure-derived fertilizers retain moisture for longer and are a source of nutrients that are released gradually throughout the phenological cycle (Fortis-Hernández *et al*., 2009). However, in the treatments that showed small plants, it is possible that it is due to the high concentrations of salts and pH in the substrates (Table 2), because it is known that the salts reduce the water potential of the water in soil, generating an ionic imbalance and producing a toxicity and imbalance (Ayuso-Calles *et al*., 2021).

For the variable stem diameter, the least favorable results were obtained with the SEEE treatment, which showed a smaller stem diameter. In the rest of the treatments, higher values were obtained with respect to the control (Figure 1b), with mean values that ranged between 4.22 and 4.95 cm. These results are similar to those reported by Rojas-Rodríguez and Ortuño (2007), where they obtained better stem thickness in onion (*Allium cepa*) produced with organic fertilizers and mycorrhizae compared to chemical fertilization.

The results of this study show that cucumber plants grown with organic fertilizers and inoculated with AMF were similar to chemical fertilization in terms of plant growth, and stem thickness, which may be due to the fact that with the symbiotic activity AMF-plant, a better use of immobile soil nutrients is obtained, and it helps improve vegetative growth (Pérez *et al*., 2021). In this sense, organic production is favorable because it saves up to 90% of the volume of chemical products, therefore, it favors the reduction of inputs and production costs.

Yield and quality of cucumber fruit produced with organic fertilizers and mycorrhizae

For the length and diameter of the fruit, significant differences ($p \leq 0.05$) were found between the treatments (Table 3), ranging between 14.73 and 19.75 cm in length, with the control treatment (ASNS) having fruits with greater length. However, the fruits of less thickness were obtained in the plants of the control treatment. The results of the fruit length are different from those reported by Alvarado *et al*. (2014), who obtained increases in the size of the tomato fruit when the plants were inoculated with *R. intraradices*.

Table 3. Effect of organic fertilizers and mycorrhizae on cucumber yield.

Treatments	Fruit length (cm)	Fruit diameter (mm)	Fruit weight (g)	Yield (t ha^{-1})	Soluble solids (°Brix)	Firmness
AEBE	19.04 a	55.1 a	275.9 a	24.88 b	4.26 a	0.47 a
AECE	18.51 a	54.1 ab	219.33 a	17.38 b	4.7 a	0.53 a
AEEE	14.99 b	53.95 ab	212.2 a	10.63 b	3.81 b	0.55 a
SEEE	14.73 b	53.78 ab	117.35 b	6.32 b	4.33 a	0.53 a
ACE	17.75 ab	47.99 b	232.58 a	16.28 b	3.93 b	0.67 a
ASNS	19.75 a	47.45 b	251.5 a	52.41 a	4.38 a	0.79 a

Means with equal letters in a column for each factor are not statistically different (Tukey, $p \leq 0.05$); the treatments are: AEBE= sand + bovine manure + Ecomic; AECE= sand + goat manure + Ecomic; AEEE= sand + equine manure + Ecomic; SEEE= soil + equine manure + Ecomic; ACE= sand + compost + Ecomic; ASNS= sand + Steiner nutrient solution.

For fruit weight, all treatments are statistically the same, except SEEE, which showed the smallest fruits with 117.35 g. However, even though the treatments with organic fertilizers were superior in terms of fruit weight, the production in substrate sand + nutrient solution (control) was higher with 52.41 t ha^{-1}, doubled the AEBE treatment, which obtained 24.88 t ha^{-1}, this being the best treatment of organic fertilizers in terms of yield. These results are similar to those reported by Galindo-Pardo *et al*. (2014), in which the highest cucumber yields were obtained in the control treatment fertilized with the nutrient solution.

In this sense, De-Oliveira *et al*. (2020) point out that organic fertilizers favor the development of greenhouse crops when they are used as substrates and that the differences detected in the yield variables assessed are due to their nutrient content and to the nature of their microbial communities. These results indicate that organic substrates represent a viable option as sources of nutrients for greenhouse cucumber when looking to decrease the use of conventional fertilizers. In this sense, Diaz-Franco *et al*. (2017) indicate that organic fertilization can be competitive with synthetic fertilization, although organic fertilizers have fewer nutrients, compared to inorganic fertilizers, the availability of these elements is more constant during the development of the crop due to the slow and gradual mineralization to which they are subjected (Iqbal *et al*., 2019).

The AEBE treatment can be an alternative to replace synthetic fertilization, since obtaining vegetables with organic fertilizers and the use of biofertilizers reduce the cost of production, provide better quality foods and help counteract the negative effects on the environment (Canchani *et al*., 2018). On the other hand, the low yield obtained in organic substrates of our study can be compensated with the price of the product, mainly in vegetables that increase from 3.31 to 5.84 times greater than the conventional one (Kwikiriza *et al*., 2018).

The firmness of the fruit is one of the important characteristics in vegetables because it defines the degree of maturity and is associated with the color and flavor of a fruit, therefore, it is related to quality. In this sense, the firmness of the cucumber fruit did not show a significant difference for any of the treatments evaluated. While for soluble solids, the treatments AECE, ASNS, SEEE and AEBE were the ones that had the highest concentration of sugars with 4.7, 4.3, 4.36 and 4.26 °Brix, respectively.

This variable reflects the quality of the cucumber produced with organic fertilizers, because it has values similar or even higher than the control. In other studies, it has been possible to increase the content of soluble solids of different vegetables when grown in organic fertilizers (Pieper and Barrett, 2009; González-Rodríguez *et al*., 2018) and one way to increase soluble solids is by increasing salinity in the root medium (Safdar *et al*., 2019; Naeem *et al*., 2020). In the present study, pots with organic treatments had a higher EC, compared to the inorganic nutrient solution, and greater or equal content of soluble solids.

For the correlation analysis between the production variables, a significant correlation ($p\leq 0.05$) was obtained between the length and weight of the fruit (r= 0.94), while for the length of fruit and yield, it was r= 0.79; likewise, the weight of the fruit with the yield, it was r= 0.83. Only the diameter of the fruit was not significant with any variable (Table 4).

Table 4. Correlation analysis between cucumber production variables with organic fertilizers inoculated with mycorrhizae.

	Length	Diameter	Fruit weight	Yield
Length	1	0.29	0.94	0.79
Diameter	0.29	1	0.65	0.22
Fruit weight	0.94*	0.65	1	0.83
Yield	0.79*	0.22	0.83*	1

*= significant variables.

Nutraceutical quality of cucumber fruit

Antioxidants are compounds capable of inhibiting or slowing oxidation by capturing free radicals that decrease the risk of many pathologies related to oxidative stress (Petruk *et al*., 2018). The antioxidant capacity and the total phenol content showed significant differences ($p\leq 0.05$) between the treatments (Table 5). The values of the antioxidant capacity ranged between 56.97 and 79.01 mg Trolox 100 g^{-1} fw, with the SEEE treatment having the best concentration. While for the content of total phenols, the AECE treatment had the highest content with 13.51 mg GAE 100 g^{-1} fw, exceeding the control by 4.49 mg.

Table 5. Nutraceutical quality of cucumber fruit obtained in greenhouse in organic fertilizer inoculated with mycorrhizae.

Treatment	Antioxidant capacity (mg Trolox 100 g^{-1} fw)	Total phenols (mg GAE 100 g^{-1} fw)	Flavonoids (mg QE 100 g^{-1} fw)
AEBE	61.11 bc	10.07 cd	0.76 c
AECE	56.97 cd	13.51 a	1.82 b
AEEE	57.11 cd	10.79 bc	0.22 d
SEEE	79.01 a	11.94 b	2.76 a
ACE	66.44 b	8.71 e	0.88 c
ASNS	53.49 d	9.02d e	0.72 c

Means with equal letters in a column for each factor are not statistically different (Tukey, $p \leq 0.05$). The treatments are: AEBE= sand + bovine manure + Ecomic; AECE= sand + goat manure + Ecomic; AEEE= sand + equine manure + Ecomic; SEEE= soil + equine manure + Ecomic; ACE= sand + compost + Ecomic; ASNS= sand + Steiner nutrient solution; DPPH= antioxidant capacity by 2,2-diphenyl-1-picrylhydracyl; the results were expressed as mg of Trolox 100 g^{-1} fresh weight. Total phenols were expressed on a basis of mg gallic acid equivalents 100 g^{-1} fresh weight. The flavonoid content was expressed in milligrams of quercetin equivalents per 100 g^{-1} of fresh weight (mg QE 100 g^{-1} fw).

It is known that the content of phenolic compounds and antioxidant capacity in fruits depends on growing conditions, agronomic practices, production season and physiological maturity (Morales-Morales *et al*., 2020), therefore, the difference of phenolic compounds and the antioxidant capacity between the control and organic fertilizers with mycorrhizae could be due to the stress generated by the low nutrient content in organic fertilizers, which causes nutritional stress in plants during growth, in addition to the stress generated by high temperatures and therefore, they promote increases in the production of phenolic compounds, increasing antioxidant capacity.

These results are consistent with other studies that report increased antioxidant capacity and phenolic content in tomatoes (Aldrich *et al*., 2010), cherry tomato (García *et al*., 2017) and cucumbers (Santiago-López *et al*., 2016) that were grown under organic fertilizer supply compared to synthetically fertilized treatments. Flavonoids are antioxidant compounds of great importance, as they exhibit various biological activities including antiallergenic, antitumor and antiviral activities (Agati *et al*., 2020). In this sense, the results obtained on the effect of organic fertilizers on flavonoids showed a significant difference ($p \leq 0.05$) due to the effect of the treatments evaluated (Table 5).

The values fluctuated between 0.22 and 2.76 mg QE 100 g^{-1} fw, being the AEEE treatment the one that had the highest concentration of flavonoids and exceeded the control by 3.8 times. The results of the AEEE treatment coincide with the results of Aguiñaga-Bravo *et al*. (2020), where they reported that flavonoids were favored with the use of organic fertilizer + 50% synthetic fertilization, improving fruit quality with the management of organic fertilizers such as bokashi. In this sense, it has been reported that the increase in the concentration of salts in the substrate causes increases in the accumulation of flavonoids in the fruit (Rosas-Medina *et al*., 2020), which are reflected in this study.

Percentage of colonization

It is known that 90% of agricultural plants form symbiotic relationships with AMF, especially vegetables and cereals (Diagne *et al*., 2020). In the percentage of mycorrhization in the cucumber root, it was observed that four treatments (AEBE, AECE, AEEE and ACE) exceeded 80% of total colonization (Figure 2). As for the structures, vesicles were the most abundant (50.0-64.8%), followed by arbuscules and hyphae. The high percentage of colonization was not reflected in cucumber yield but had a significant impact on quality. In this sense, Cavagnaro (2014) mentions that inoculation of arbuscular mycorrhizae and compost can have an important role in agricultural systems, especially those that place a strong emphasis on biologically regulated nutrient supply systems.

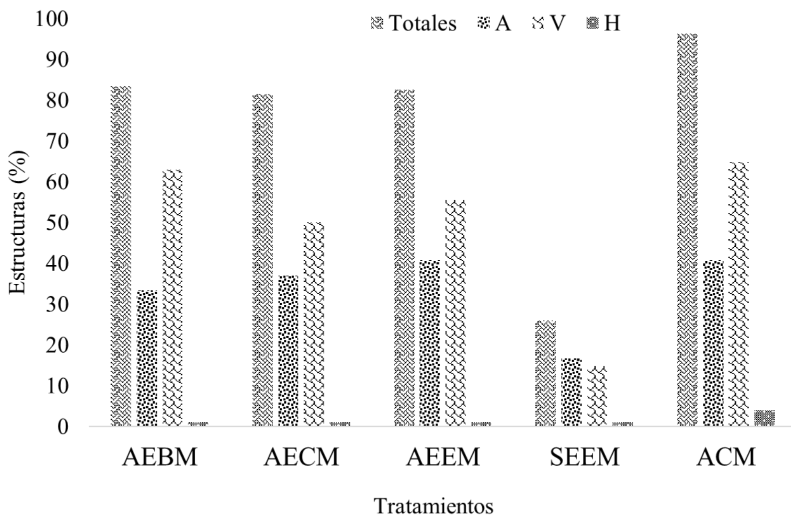

Figure 2. Percentage of mycorrhizal colonization in cucumber root with organic substrates. Percentage of mycorrhization of H= hyphae; V= vesicles; E= spores; A= arbuscules; AEBM= sand + bovine manure + Ecomic; AECM = sand + goat manure + Ecomic; AEEM= sand + equine manure + Ecomic; SEEM= soil + equine manure + Ecomic; ACM= sand + compost + mycorrhizae.

Conclusions

Organic fertilization and the use of mycorrhizae in cucumber cultivation had a positive response in plant growth and fruit quality (soluble solids, antioxidants, phenols and flavonoids); however, it was affected in yield, where the control obtained the best results.

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