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Article

Effect of biofertilizer on Hass avocado phenology

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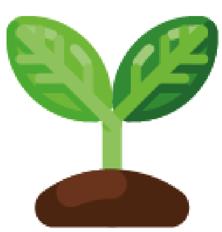
Abstract

The factors associated with environmental care trigger interest in the development of organic agriculture, recognized as an economically efficient, socially just and ecologically sustainable alternative, which contributes to reducing the negative impacts attributed to conventional agriculture; for this reason, this research studied eight treatments of organic fertilizers in Coaxtlahuacán, municipality of Mochitlán, Guerrero, Mexico, from November 2020 to November 2021 in an eight-year-old Hass avocado orchard. The objective was to evaluate the phenological behavior of avocado trees nourished with organic fertilizers from bovine manure: 50 and 75 kg year^{-1}, applied in solid and liquid form; mixed with and without organic micronutrients, which combined formed eight treatments, plus a control (water), arranged in a randomized block design with four replications; one tree as an experimental unit. The fruit reached physiological maturity in November with polar and equatorial diameters of 9.8 and 7.5 cm, respectively. The application of 50 SMM (50 kg of solid manure + micronutrients) and 75 SM (75 kg of solid manure) presented the best polar diameter (7.5 cm) and 50 SM (50 kg of solid manure) showed the best equatorial diameter (5.1 cm). The best result showed the higher number of vegetative flushes in March (9.5 shoots branch^{-1}), and the higher number of flower flushes in February (10.3 shoots branch^{-1}); of these, the application of 50 SM (2.9 shoots branch^{-1}) was superior to the other treatments, while 50 SMM was the best for the flower shoots (3.3 shoots branch^{-1}).

Keywords:

Persea americana Mill., organic fertilizers, organic production.



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Introduction

The family Lauraceae, belonging to the order Laurales, is considered, along with others, to be the most primitive of the dicotyledons. There are numerous economically important species; they are trees that provide excellent woods, such as laurel and very fine essential oils; avocado is perhaps the only one with an edible fruit, which is rich in carbohydrates, vitamins (A, B, C, D, E, K) and minerals, which makes it a 100% nutritious fruit (Jiménez *et al*., 2005).

Michoacán is considered the leading producer nationwide of avocado (*Persea americana* Mill.) of the 'Hass' variety, while Guerrero ranks fifth, with 2 466 ha planted a production of 13 409 t and an average yield of 6.9 t ha^{-1}, which ranked first in avocado production worldwide in 2017 (SIAP, 2017), which leads to environmental prejudices and the progression of the crop towards areas with greater climate and soil limitations (Anguiano *et al*., 2006).

Climate is not a factor that can be controlled by man; however, the soil can be conveniently managed for the benefit of the crop and agricultural production (Sullivan, 2004). For most producers, the fastest solution to correct low soil fertility is the application of chemical fertilizers; nevertheless, over time and due to the conditions in which it is found, the application of these inputs threatens the sustainability of the soil and the environment.

Nonetheless, avocado producers are reluctant to use organic nutrition because it is associated with lower nutrition, lower yield, and small fruit size according to SENASICA (2017); Damián *et al*. (2021) mention that organic nutrition based on ferments, composts, or vermicompost is a viable alternative for avocado production. Organic nutrition has gone from being the simple application of manure waste and compost to products with greater nutritional efficiency, with the advantage of being less harmful to the environment (Gómez-Cruz *et al*., 2010).

Moreover, they contribute to the short- and long-term sustainability of soil fertility and the increase of microbial activity and soil organic matter (Salinas *et al*., 2005). Currently, the way to supply the nutritional elements that the soil cannot provide to avocado crops is through the application of synthetic fertilizers to the soil or to the leaves (Lavaire, 2013), in short, under the conventional agriculture approach. According to the literature and research, no studies have been carried out in Guerrero on the organic nutrition of avocados (Larios *et al*., 2008).

For this reason, the following research work was proposed to obtain more information about organic nutrition since it is a promising alternative as there are high levels of pollution in the natural environment due to the abuse of agrochemicals (Tapia-Vargas *et al*., 2014), which lead us to think of ecological alternatives for the production of our food with the minimum risk that they contain substances harmful to human health.

Avocado nutrition must be within ecological management, such as the use of organic fertilizers that were evaluated in order to know their effect in each phenological stage of the crop (Salazar-García, 2017), in order to select the most effective one that contributes to better crop management, that is, both the right time and the amount for its application; therefore, this research aimed to evaluate the effect of organic biofertilizers on the flowering and fruit quality of avocado of the Hass variety for the development of an organic management plan.

Materials and methods

The genetic material under study was avocado (*Persea americana* Mill.) of the Hass variety. In December 2020, a tour was carried out in the Coaxtlahuacán orchard to select 36 four-year-old avocado trees; in these trees, for each cardinal point, a branch of 1 to 1.5 m in length and 1 to 2 cm in diameter at the base of the branch was chosen by using tape measure and a vernier; these branches were subjected to eight organic nutrition treatments in order to evaluate each one; likewise, from January 2018, three applications of already mineralized manure were made according to the treatment design with a three-month interval for each application.

Data collection began from the time the first shoots (vegetative and inflorescences) emerged, which consisted of quantifying these shoots in the four cardinal points. Likewise, data were collected from

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the emergence of the first fruit in April 2018, which consisted of choosing 5 fruits branch^{-1}, according to the cardinal points, to measure the polar and equatorial diameters by fruit until November of the same year. Data were recorded every 15 days for 12 months.

The study variables were: number of vegetative shoots branch^{-1}, which were quantified as shoots without flowers or fruits; number of inflorescences branch^{-1}, the inflorescences of the selected branches were quantified; fruit growth dynamics, from fruit set to physiological maturity, its polar and equatorial diameters were measured with a vernier.

The biofertilizers were formulated according to the treatments with the following factors and levels: factor I. Bovine manure dose: level 1: 50 kg plant^{-1} (a) and level 2: 75 kg plant^{-1} (b); factor II. Manure presentation: level 1: liquid form (c) and level 2: solid form (d), as shown in (Table 1).

Table 1. Design of treatments with biofertilizers and micronutrients.

	Treatments	
T1= 50 kg liquid manure plus micronutrients= 50 LMM	T2= 50 kg liquid manure without micronutrients= 50 LM	T3= 50 kg solid manure plus micronutrients= 50 SMM
T4= 50 kg solid manure without micronutrients= 50 SM	T5= 75 kg liquid manure plus micronutrients= 75 LMM	T6= 75 kg liquid manure without micronutrients= 75 LM
T7= 75 kg solid manure plus micronutrients= 75 SMM	T8= 75 kg solid manure without micronutrients= 75 SM	T9= control (water alone) CONT

Descriptive analysis

The data on the variables of fruit polar and equatorial diameters, number of vegetative shoots, and number of flower shoots under study were subjected to an average analysis using the program.

Statistical analysis

For all the variables under study, an analysis of variance and a Tukey mean test ($p\leq 0.05$) were performed using the statistical package of SAS ver. 6.12 (2010). Likewise, orthogonal contrasts of the treatments were performed for all variables.

Results and discussion

Polar diameter of Hass avocado fruits

In the analysis of variance, highly significant differences were found between sampling dates, treatments, and interactions of dates by treatments and dates by orientation ($p\leq 0.05$) in the polar diameter.

Increase in fruit polar diameter during the sampling dates

In relation to the sampling dates (Figure 1), it can be seen that the diameter that the fruit reached at physiological maturity went from 2.25 cm in April to 9.79 cm in November; that is, the fruit grew 7.6 cm during that period. During the period from April to July, the fruit grew 7.8 cm on average, which is equivalent to 79% of the total growth, and it grew by 21% from August to November.

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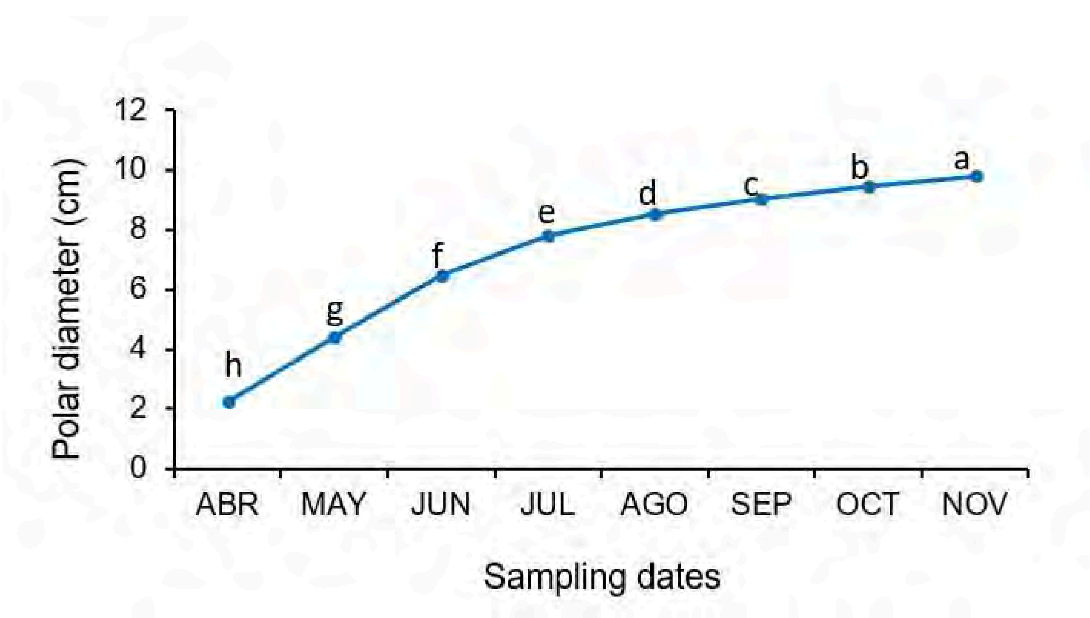
Figure 1. Increase in polar diameter of fruits measured from April to November in a Hass avocado orchard nourished with organic fertilizers in the town of Coaxtlahuacán, municipality of Mochitlán, Guerrero.



Effect of treatments on fruit polar diameter

The fruit polar diameter of treatment 50 SMM and 75 SM was 7.5 cm and they were statistically superior to the CW; treatments 50 SM and 75 SMM showed 7.1 cm in diameter, while 50 LM showed 6.8 cm in diameter; however, although they had higher values, they were not significantly different from T5 (75 LMM) (7.4 cm), T1 (50 LMM) (7.3 cm) and T6 (75 LM) (7.2 cm) (Figure 2).

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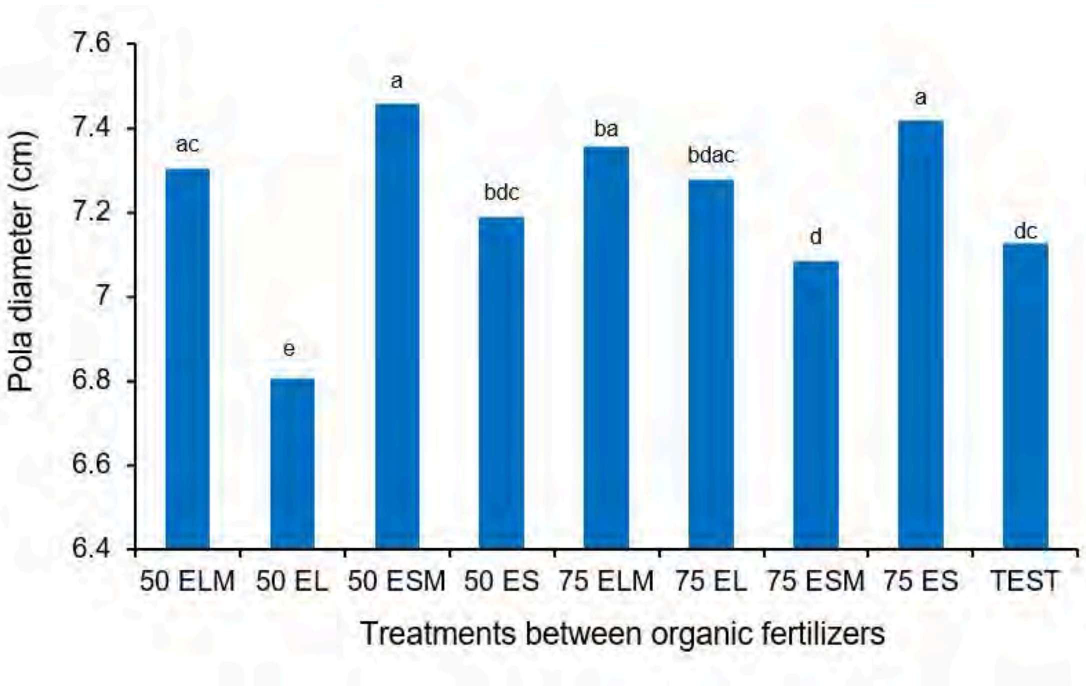
Figure 2. Fruit polar diameter due to the effect of organic treatments applied in a Hass avocado orchard in the community of Coaxtlahuacán, municipality of Mochitlán Guerrero. TEST (control= CONT, water), 50 and 75 (50 and 75 kg of manure), E (manure= M), L (liquid), S (solid), M (micronutrients).



In this regard, it coincides with what Bernal and Díaz (2006; 2008) mention, that the application of nutrients is very important to improve the quality and yield of avocados; N promotes fruit formation, P intervenes in the formation of reproductive organs and accelerates fruit ripening and K participates in the formation, quality and weight of avocado fruits, coinciding with the development of phenological maturity with López-López and Cajuste-Bontemps (1977).

In relation to the polar diameter during the sampling period due to the effect of the organic treatments (Figure 2), obtained from orthogonal contrasts, all treatments were greater than the control, with an average of 0.11 cm; the best dose used was 75 kg of manure, with a difference of 0.1 cm of polar diameter compared to 50 kg; as for the dose of 50 kg, it turned out to be more functional applied to the soil in solid form, with a difference of 0.27 cm compared to the dose of 50 kg applied liquidly; regarding the dose of 50 kg of manure applied to the soil in liquid form, the one that obtained a greater assimilation was the one to which micronutrients were added, with a difference of 1.5 cm compared to the one that did not include micronutrients.

Regarding the 50 kg dose that was applied solidly, the one that included micronutrients was also more efficient, with a 0.3 cm difference compared to that without micronutrients; nevertheless, regarding the dose of 75 kg applied to the soil in a solid form, the most effective was the one that did not include micronutrients, with a difference of 0.31 cm compared to the one that included micronutrients.

In the analysis of variance, highly significant differences were found between sampling dates, treatments, and interactions of dates by treatments and treatments by orientation (*p*# 0.05) in the equatorial diameter. In relation to the sampling dates (Figure 3), it can be seen that the diameter reached by the fruit at physiological maturity in November was 6.49 cm. From April to July, the fruit had an average of 5.21 cm, which is equivalent to 80% of the total growth; it grew by 20% from August to November.

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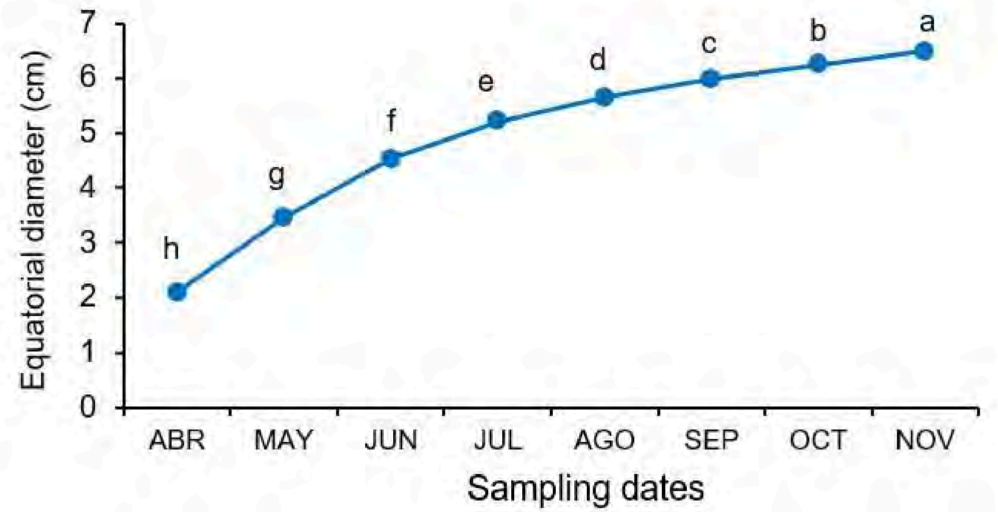
Figure 3. Increase in equatorial diameter of fruits measured from April to November in a Hass avocado orchard nourished with organic fertilizers in the locality of Coaxtlahuacán, municipality of Mochitlán, Guerrero.



Effect of treatments on fruit equatorial diameter. Regarding equatorial diameter, T4 (50 SM) (5.1 cm) was statistically superior to T9 (CONT), T7 (75 SMM) (4.8 cm), T1 (50 LMM), and T2 (50 LM) (4.7 cm); however, although it had a higher value, it was not significantly different from the rest of the treatments (Figure 4).

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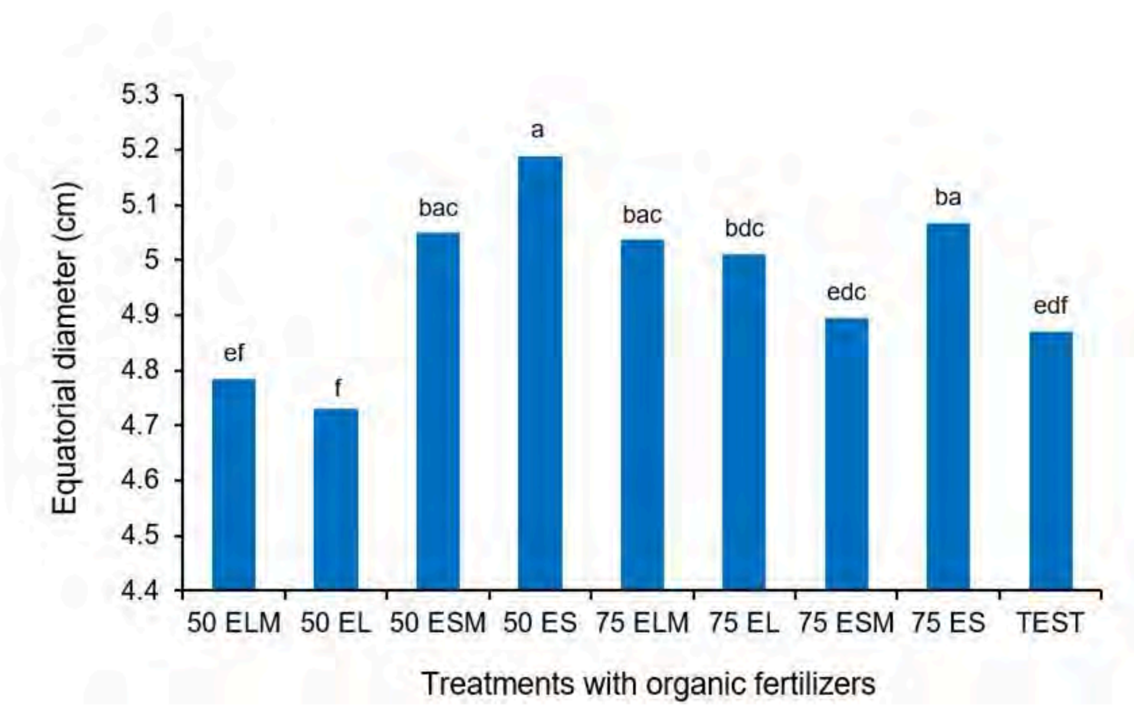
Figure 4. Fruit equatorial diameter due to the effect of organic treatments applied in a Hass avocado orchard in the community of Coaxtlahuacán, municipality of Mochitlán, Guerrero. TEST (control= CONT, water alone), 50 and 75 (50 and 75 kg of manure), E (manure= M), L (liquid), S (solid), M (micronutrients).



In the analysis of variance obtained from orthogonal contrasts, there were significant differences in treatments vs control; dose 50 vs dose 75; 50 SMM vs 50 SM; 75 SMM vs 75 SM and there were highly significant differences in 50 LM vs 50 SM ($p \leq 0.05$). In relation to the equatorial diameter due to the effect of organic treatments (Figure 5), obtained from orthogonal contrasts, all treatments were superior to the control, with an average of 0.1 cm; the best dose used was 75 kg of manure, with a difference of 0.7 cm of equatorial diameter compared to 50 kg; regarding the dose of 50 kg, it was more functional applied to the soil in solid form, with a difference of 0.36 cm compared to the dose of 50 kg applied liquidly to the soil; the application of solid manure without foliar micronutrients was more efficient than the one to which micronutrients were added, with 0.15 cm; similarly, the dose of 75 kg of solid manure was more effective than the one that omitted the micronutrients, with a 0.17 cm difference.

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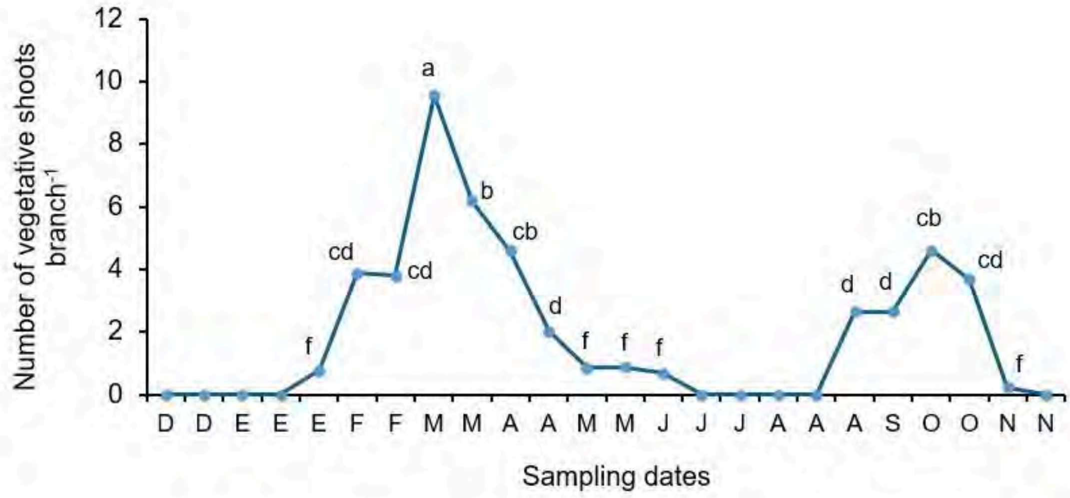
Figure 5. Number of vegetative shoots emitted in a Hass avocado orchard in the community of Coaxtlahuacán, municipality of Mochitlán, Guerrero.



Increase in vegetative shoots during the sampling period

Regarding the number of vegetative shoots, two important shooting peaks were clearly observed: the first from the second half of February to the first half of June, the second shooting period was from the second half of August to the second half of October; of these vegetative flushes, March (9.5 shoots branch^{-1}) was statistically higher than August, September (2.6 shoots branch^{-1}), January (0.7 shoots branch^{-1}), May (0.8 shoots branch^{-1}), November (0.2 shoots branch^{-1}), February (3.8 shoots branch^{-1}), April (4.5 shoots branch^{-1}) and October (4.6 shoots branch^{-1}). The periods that showed statistically lower values or no vegetative shoots were from November to January and from May to the first half of August (Figure 5).

Effect of treatments on vegetative shoots

As for vegetative shoots, T4 (50 kg SMM) (2.9 shoots branch^{-1}) was statistically superior to T1 (50 LMM), T6 (75 LMM) and T7 (75 SMM) (1.9, 1.5 and 2 shoots branch^{-1}, respectively); although they had higher values, they were not significantly different from T2 (50 kg of liquid manure without micronutrients) (2.7 shoots branch^{-1}), T3 (50 SMM) and T5 (75 LMM) with 2.2 shoots branch^{-1}; T8 (75 SMM) and T9 (CONT) (1 shoot branch^{-1}) presented statistically lower values than the other treatments.

Each treatment consists of different degrees of nutrition; however, the nutrients used for flowering coincide with Fersini (1980); Espíndola *et al*. (2014) in flowering season according to soil and climatic conditions (García, 1983).

Regarding the number of vegetative shoots during the sampling period due to the effect of organic treatments, obtained from orthogonal contrasts, all treatments were higher than the control with one shoot; the best dose used was 50 kg of manure, with a difference of 1 shoot compared to the dose of 75 kg; as for the dose of 50 LMM, it had a greater effect than the dose of 50 LM with 1 shoot; in relation to the dose of 50 SM, it was more efficient than the dose of 50 SMM with 2.9 shoots branch^{-1}; for its part, the dose of 75 LM turned out to be more efficient compared to the dose of 75 SM with 1 shoot; the dose of 75 LMM was better than the dose of 75 LM with 2.2 shoots; likewise, the dose of 75 SMM was more efficient than the dose of 75 SM, with 2 shoots branch^{-1} (Figure 6).

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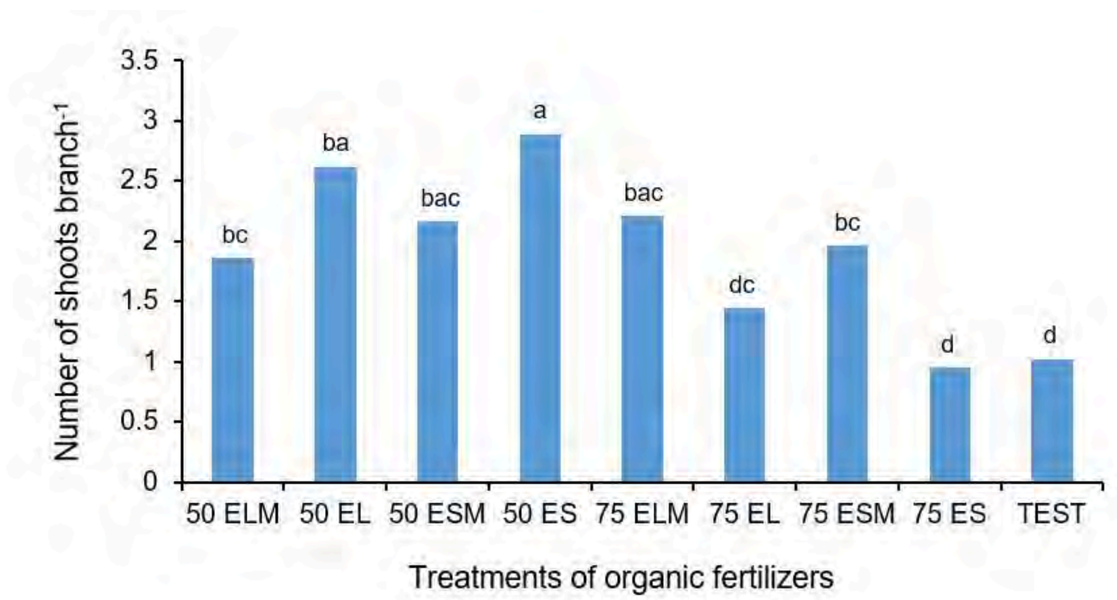
Figure 6. Vegetative shoots of Hass avocado due to the effect of organic treatments applied in the community of Coaxtlahuacán, municipality of Mochitlán Guerrero. TEST (control= CONT, water alone), 50 and 75 (50 and 75 kg of manure), E (manure= M), L (liquid), S (solid), M (micronutrients).



The analysis of variance yielded highly significant differences between sampling dates, treatments, and interactions of dates by treatments and yielded significant differences in orientation ($p \leq 0.05$) in the flower shoots.

Number of flower shoots during the sampling period

Regarding the emission of flower shoots in avocado trees in the locality of Coaxtlahuacán, there were two peaks: the first from December to April and the second from August to September, as in other avocado-growing regions in Mexico; specifically, in the state of Michoacán, there were three to four flower shoot flushes, the usual from December to February, that of March from March to April, and that of August or 'crazy' from August to September (Rocha *et al*., 2010).

The highest number of flower shoots occurred in the second half of February (10.3 shoots branch^{-1}), which were statistically higher than those that occurred (3 to 3.9 shoots branch^{-1}) but they were not statistically higher than the first half of February (8.5 shoots branch^{-1}) and the first half of March (8.7 shoots branch^{-1}); the statistically smaller number of shoots occurred in December, April, August, and September (2.4, 1.2, 0.9, and 0.59 shoots branch^{-1}, respectively) (Figure 7). The results are consistent with Nelson *et al*. (2010) in the different options of organic production reflected in flowering and fruit set.

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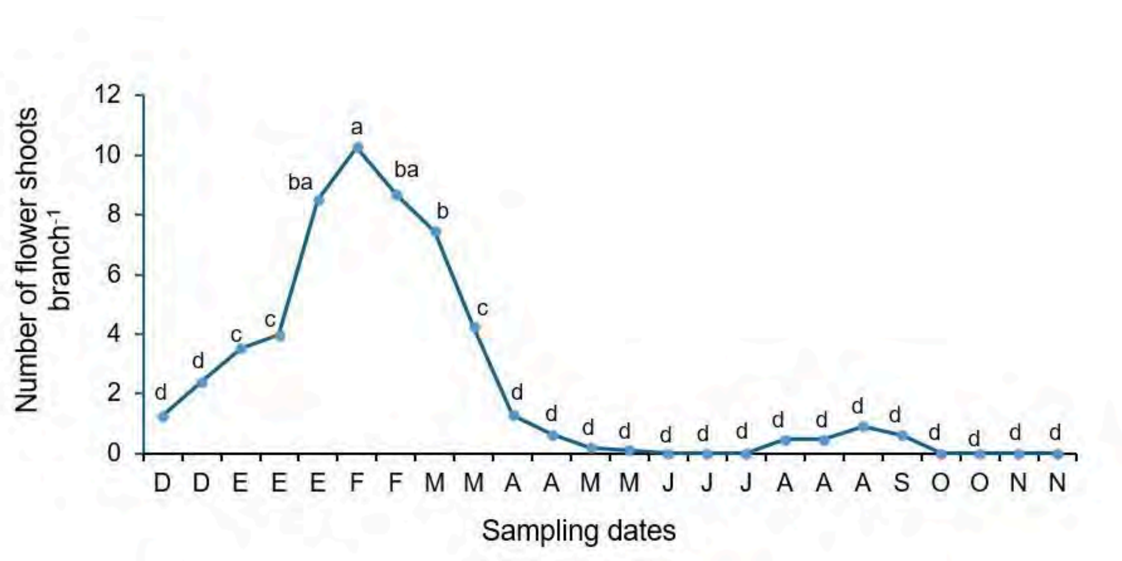
Figure 7. Number of flower shoots emitted in a Hass avocado orchard in the locality of Coaxtlahuacán, municipality of Mochitlán, Guerrero.



Effect of treatments on the emission of flower shoots

Regarding the flower shoots (Figure 8), T3 (50 SMM) (3.3 shoots branch^{-1}) was numerically higher than T4 (50 SM), T7 (75 SMM), T8 (75 SM), T9 (CONT) (1.2, 2, 1.65, 1.46 shoots branch^{-1}, respectively) and T5 (75 LMM) (2.35 shoots branch^{-1}); nevertheless, despite the fact that they had higher values, they were not significantly different from T1 (50 LMM), T2 (50 LM) and T6 (75 LM) (2.92, 2.86 and 2.67 shoots branch^{-1}, respectively). Nutrition increases flowering in some avocado treatments with organic fertilizers, which coincides with some authors such as Villalva-Morales (2015); Nelson *et al*. (2010); Espíndola *et al*. (2014).

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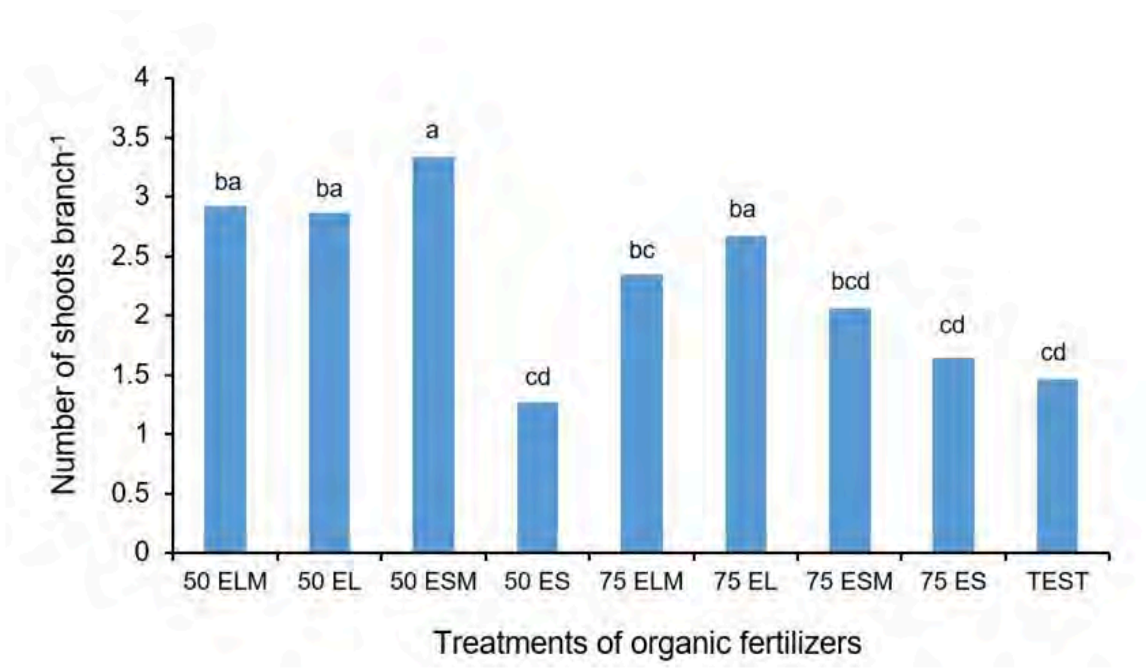
Figure 8. Hass avocado flower shoots due to the effect of organic treatments applied in the locality of Coaxtlahuacán, municipality of Mochitlán Guerrero. TEST (control= CONT, water alone), 50 and 75 (50 and 75 kg of manure), E (manure= M), L (liquid), S (solid), M (micronutrients).



In the analysis of variance obtained from orthogonal contrasts, highly significant differences were obtained in: treatments vs control; 50 SMM vs 50 SM; in the dose of 50 kg vs the dose 75 kg M; 50 kg LM vs 50 kg SM; 75 kg LM vs 75 kg SM ($p \leq 0.05$). Regarding the number of flower shoots during the sampling period due to the effect of organic treatments, obtained from orthogonal contrasts, the following occurred.

All treatments had higher values than the control, with one flower shoot difference; the best dose used was 50 kg of manure with 2.6 shoots branch^{-1} compared to 75 kg with 2.1 shoots branch^{-1}; as for the dose of 50 kg of solid manure (2.3 shoots branch^{-1}), it was found to have less effect than 50 kg of liquid manure (2.9 shoots branch^{-1}); the dose of 50 kg of solid manure with micronutrients was more efficient than the 50 kg of solid manure without micronutrients, with 3.3 shoots branch^{-1}; the dose of 75 kg of liquid manure (2.5 shoots branch^{-1}) was more effective than the 75 kg of solid manure, with 1.9 shoots branch^{-1}.

The nutrition of each of the treatments coincides with the normal flowering in López-López and Cajuste-Bontemps (1977); Salazar-García (2002); Larios *et al*. (2008). They only talk about the increase, but the reports are in tonnes of fruit per hectare.

Conclusions

The fruits reached their maximum polar and equatorial diameters (physiological maturity) in November, while the highest number of vegetative flushes were in March and that of flower flushes in February. The application of 50 and 75 kg of solid manure, with and without micronutrients, presented the best polar and equatorial diameters, as well as the highest number of vegetative and flower shoots. The perspectives of each of the treatments is to align the needs of avocado trees with biofertilizers, macro and micronutrients must be balanced, looking for the ideal raw materials to generate a competitive alternative.

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