Article

Compost response on fertility, soil moisture, nutritional content in leaves and productivity in olive trees

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Abstract

The use of organic residues represents a good alternative for the vegetable nutrition of the olive tree. The objective was to evaluate the effect of the compost application on the physical and chemical conditions of the soil, nutritional level in leaves, soil moisture and olive productivity in desert regions. The evaluation was carried out in an orchard located in the Caborca region, Sonora, Mexico during the years 2018 and 2019. The cultivar used was Manzanilla de Sevilla, with a spacing of 10 x 5 m (200 trees ha^{-1}). The evaluated treatments were: 1) compost + wheat straw (C+P); and 2) absolute control (without compost or straw) (T). The parameters evaluated were: soil fertility, nutritional content in leaves, soil moisture, yield and fruit quality. The experimental design used was completely randomized with four replications. With the application of compost and wheat straw (C+P) the concentration of most of the edaphic nutrients, the content of organic matter, the cation exchange capacity and the salinity of the soil increased. In plant it increased the nutritional content in leaves. On the other hand, soil moisture, yield and quality of olives were not statistically affected with the incorporation into the soil of compost and wheat straw (C+P), in relation to the control (T). Despite an improvement in the soil, the application of compost in two years has not increased productivity in the olive tree.

Keywords: *Olea europaea* L., organic matter, quality.

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Introduction

The incorporation of organic residues into the soil, as a source of plant nutrition in crop production and at lower costs, represents an excellent alternative for this purpose. Composting serves to convert this waste into a product of great benefit that is incorporated into the soil as organic fertilizer, which improves its physical and nutritional conditions (Trinidad and Velasco, 2016). The most significant effect that occurs on a soil when organic waste is added to it is the increase in its organic matter content.

Using organic fertilizers routinely on agricultural soils increases the content of organic matter in the medium and long term and, with it, the availability of nutrients. That is, plants have greater availability of nutrients (N, P, K, Ca, Mg and S) and micronutrients (Fe, Mn, Cu, Zn Ni, B, Mo and Cl) with a greater cation exchange capacity (CEC) (Trinidad and Velasco, 2016). Huddleston and Ronayne (1990), mention that the best responses of soils to the application of organic fertilizers are those of medium to coarse texture, such as loamy, sandy-loamy, clay-loamy and sandy soils.

The addition of organic fertilizers to the soil improves its physical and chemical conditions and stimulates biological activity (Bulluck *et al*., 2002; Roldan *et al*., 2003; Hargreaves *et al*., 2008; Lovieno *et al*., 2009). Organic fertilizers help to improve the structure, stability of aggregates, retention of soil moisture and reduce the loss of nutrients by reducing the runoff of irrigation water and rain and thus avoid soil erosion (Bastida *et al*., 2007; Tarango, 2010; Arenas *et al*., 2015). They also increase the capacity of the soil to retain exchangeable cations (López-Piñeiro *et al*., 2007; Weber *et al*., 2007). The speed of mineralization of organic matter (OM) depends on the physical and chemical nature of the organic waste, the microorganisms that took part in the decomposition and the physical-chemical conditions of the process (humidity, aeration, temperature and pH) (Trinidad and Velasco, 2016).

Two of the important mineralization results in OM are humic and fulvic acids, which are responsible for many of the improvements exerted by humus (Brunetti *et al*., 2005). In this regard, Brunetti *et al*. (2005) mention that the content of humic acids in the soil increased when plant residues from olive trees were incorporated.

On the other hand, the addition of OM to the soil favors the proliferation of beneficial microorganisms, such as bacteria, fungi and actinomycetes. These microorganisms participate in the different OM degradation processes, oxidation and reduction of nutrients and inhibition of some soil pathogens Romero-Lima (1997); Ros *et al*. (2008). It also represents a potential for controlling soil pathogens (Hoiting *et al*., 1991; Hadar and Mandelbaun, 1992).

In the cultivation and production of olive trees under the conditions of soil and management in the region of Caborca, Sonora, there is not the necessary and adequate information on the productive capacity of the olive tree. The application of organic fertilizers (compost) as a source of fertilizer, without the use of chemical fertilizers. The objective of the present work was to determine the effect of the application of compost in the physical and chemical conditions of the soil, nutritional level in the leaves of the plants, soil moisture, and productivity of the olive tree in desert regions.

Materials and methods

Description of the study area

The work was carried out on lands of the Rural Production Society (SPR) 'Campo Aguilar' located in the region of Caborca, Sonora, located at 30° 48' 49'' north latitude and 112° 54' 18'' from west longitude and an altitude of 44 m. The climate is desert with an average annual temperature of 22 °C. January is the coldest month with 4.6 °C and July the hottest with 40.2 °C. Annual precipitation is less than 200 mm with evaporation greater than 2 300 mm per year (Robles, 2001).

Soil characteristics

The soil of the commercial olive lot where the evaluation was established presented a loamy texture in the surface layer (0-30 cm) and a sandy-loam texture in the deepest layer (30-60 cm). It is low in organic matter content (0.6%), good drainage, a slightly alkaline pH (7.3) and poor in nitrogen (5.8 ppm) and phosphorus (10.1 ppm).

Agronomic management

The evaluation was carried out in an eight-year-old olive orchard for two cycles (2018 and 2019). The cultivar used was Manzanilla de Sevilla, with a rectangular plantation frame of 10 x 5 m (200 trees ha^{-1}). The experiment was established under the drip irrigation system. Two dripper hoses with 1 m of separation between them were used, located on the soil surface on each side of the planting line, with three drippers per line with an output of 8 L h^{-1} (six drippers per tree). Irrigation was applied every week for a duration of 12 to 24 h and the applied sheet was 12 000 m^3 ha^{-1}.

The rest of the agronomic management was carried out by the cooperating producer. As it is an orchard to produce organic olives, only authorized products were applied. The only agrochemical applied was Spinosad (1 L ha^{-1}) twice a year for the control of the olive fly (*Bactrocera oleae*). In addition, in general throughout the orchard, 5 applications per year of worm tea leachate of the californian species (*Eisenia foetida*) were made in doses of 5 L ha^{-1}.

The perennial weeds that were presented were: bindweed (*Convolvulus arvensis* L.), stafiate (*Ambrosia confertifolia* D C.), chamizo (*Atriplex canescens* (*pursh*) *Brandegee*) and the control of them was carried out by means of mechanical pruning with an attached blade to a tractor, the cut weeds were spread over the soil surface.

Evaluated treatments

The evaluated treatments were: 1) application of compost plus wheat straw (C+P) and 2) control without application of compost or wheat straw (T). In the C+P treatment, 60 kg of compost plus 13 kg of wheat straw were applied per tree in November 2017. Later, in June 2018, the second application of compost alone was made, in doses of 120 (kg $tree^{-1}$). The application was made on the soil surface, because in fruit trees it is difficult to incorporate it into the soil profile (Cortes, 2011). The compost and wheat straw were applied to a trench approximately 20 cm deep, remaining uncovered (not buried) on the surface of the soil, on both sides of the planting line, (approximately 1.2 m from the trunk of the trees) just below the irrigation hose.

The compost used was produced by the cooperating producer, who used for it, vegetable residues from the pruning of olive trees, enriched with cattle manure. The nutritional characteristics of the compost used are presented in Table 1. In the control (T), no compost or wheat straw was applied.

Table 1. Nutrient content of the compost used in the Manzanilla de Sevilla olive tree during the years 2018 and 2019.

N	P	K	Mg	Ca	Zn	Fe	Mn	Cu	Na	EC	CEC	pH
(%)					(ppm)					(dS m^{-1})	(meq 100 g^{-1})	
4.8	0.31	0.31	0.04	0.71	4	75	72	1	893	6.1	64.7	7.04

Evaluated parameters and statistical analysis

To measure the effect of changes in the physicochemical characteristics of the soil, in each treatment, a sampling was carried out at two soil profiles (0-30 and 30-60 cm) in the month of July in both years. To obtain the sample, four subsamples were combined, one in each repetition obtained along the planting line under the irrigation hose. Regarding the tree, the nutritional content of the leaves of the trees corresponding to each treatment was measured. For this, a foliar sampling was carried out on July 4, 2018 and July 11, 2019.

The foliar sampling was carried out according to the methodology recommended by Fernandez (2001), for which 100 leaves corresponding to the trees of each treatment were collected, located in the four cardinal points, at an average height of 2 m corresponding to healthy plants, no pest damage. The soil moisture content was determined at two depths (40 and 80 cm) during the period from February 22, 2018 to June 17, 2019, using Irrometer (EC) Watermark brand soil moisture meters placed 1 m from the tree trunk and 30 cm from the dropper. To measure productivity, the yield (kg $tree^{-1}$) was determined, which was the average of seven harvested trees and the quality of the fruit (weight and diameter of the fruit, as well as the bone pulp ratio) was determined by taking 100 fruits at random per repetition at harvest time. The harvest was carried out manually on August 13 in 2018 and on September 3 in 2019.

The experimental design used was completely randomized with four repetitions, taking a row with 30 trees (1 500 m^2) as the experimental unit and the tool the seven central trees (350 m^2). Only the variables of soil moisture, yield and fruit quality were statistically analyzed using the FAUANL version 2.7 analysis of variance program (Olivares, 2016). The mean separation was carried out according to the minimum significant difference (DMS) at 5%.

Results and discussion

Soil analysis

The effect of the application of compost and wheat straw on the content of (OM) in the soil is shown in Table 2. The results indicated that in the control the content of OM was extremely poor in the two depths (Castellanos *et al*., 2000) and more accentuated in the depth of 30-60 cm. The application of compost and straw (C+P) increased the OM in the surface layer of the soil. During the two years of study, the OM content increased from 0.72% in the control, to 2.38% in the treatment (C+P) in 2018 and from 0.85% to 2.71% in 2019 in the depth of the soil between 0- 30 cm. At the deeper soil depth (30-60 cm) the increase in OM was lower (Table 2). In this regard, Trinidad and Velazco (2016) mention that it is a fact that with the application of organic waste to the soil, the OM content is increased and with it the availability of nutrients.

The concentration of salts in the soil (EC) increased, due to the application of the C+P treatment, mainly in the surface layer of the soil, due to the fact that one of the components of the compost was bovine manure and in this regard Seguel *et al*. (2013) mention that the application of manure to the soil can increase salinity. In 2018, at the depth of 0-30 cm, the content of salts in the soil increased from 1.61 to 3.13 dS m^{-1} with the application of the C+P treatment, while in the 30-60 cm layer the increase was less than 1.74 to 2.2 dS m^{-1} for both treatments (Table 2).

In 2019, the concentration of salts in the soil decreased in relation to the previous year for both treatments. This reduction was probably due to the effect of salt washing by the irrigation water applied during the two cycles, mainly on the treatment where the C+P treatment was applied. In this regard, it is mentioned that the most used method for the recovery of saline soils is the washing or leaching of soluble salts with low salinity water (Aguilar, 2013).

The electrical conductivity (EC) reflects the content of soluble salts in water and in the soil, and when its content is high, phytotoxic effects occur on plant growth. However, Grijalva *et al*. (2010) mention that the olive tree is tolerant of soil and water salinity without detriment to its productivity. On the other hand, Castellanos *et al*. (2000), indicate that the olive tree can withstand concentrations of up to 4 dS m^{-1} without affecting the yield. Therefore, the values of EC detected by the laboratory analysis in the present work, they do not represent a problem for the production of the culture under these conditions.

The cation exchange capacity (CEC) was another of the parameters that increased with the application of the C+P treatment, mainly in the surface layer 0-30 cm in both years of evaluation in relation to the control in 2018 (Table two). In this regard, Guerrero (1996) mentions that the presence of humic substances increases the cation exchange capacity (CEC) of soils by forming clay-humic complexes (Guerrero, 1996).

The cation exchange capacity designates the processes of: (a) adsorption of cations by the exchange complex from the soil solution; and (b) release of cations from the exchange complex into the soil solution. This property is attributed to clay (mineral colloid) and humus (organic colloid), so that the CEC is influenced by: the amount and type of clay, the amount of humus and the pH or reaction of the soil (Sánchez, 2007).

With regard to the nutrients analyzed (Table 2) in the two years of evaluation, the greatest variation of these occurred in the surface layer (0-30 cn) with the C+P treatment, because the compost was applied on the surface without incorporating it into the soil, so the effects of this application were minimal in the 30-60 cm layer. In the two years of evaluation, the application of the C+P treatment increased the content of the nutrients analyzed at both depths.

However, the content of N and P in the soil are very deficient at both depths in 2019 (Table 2). In this regard Giese *et al*. (2011) mention that, in arid and semi-arid areas, such as northwestern Mexico, organic production is limited by the lack of nitrogen in the soil. On the other hand, Heeb *et al*. (2005) mention that, when applying compost to the soil, in the first year, there is an availability for the plant of 70-80% of phosphorus and 80-90% of potassium contained in it, but not the nitrogen which must be mineralized to be absorbed by the plants, mineralizing only 11% in the first year, so if it is not supplied properly, a deficiency of this element is generated.

Table 2. Soil nutrient content in two treatments at two depths in the Manzanilla de Sevilla olive cultivar in the Caborca region, Sonora during the years 2018 and 2019.

Parameter	Deep 0-30 cm				Deep 30-60 cm				Reference Level[Z]
	Control		C+P		Control		C+P		
	2018	2019	2018	2019	2018	2019	2018	2019	
OM (%)	0.72	0.85	2.38	2.71	0.09	0.16	0.27	0.29	> 2
EC (dS m^{-1})	1.61	1.4	3.13	1.52	1.74	1.37	2.2	1.47	<4
CEC (meq/100g)	29.9	27.7	40.8	27.3	16.5	21.4	21.5	21.3	5-50
Ph	7.3	8.7	7.3	8.21	7.2	8.75	7	8.77	7
N-NO_3 (ppm)	5.4	6.7	6.7	11.7	3.5	2.76	4.1	3.68	30
P (ppm)	9.5	20.3	9.9	27.7	10.4	21.3	9.9	21.6	30
K (ppm)	494	291	466	293	256	210	572	219	350
Ca (ppm)	3547	4171	5799	4194	1896	3298	2483	3222	2000
Mg (ppm)	883	550	885	504	498	366	618	373	250
Na (ppm)	718	375	781	338	516	312	590	357	< 200
$CaCO_3$ (%)	4	5.73	4	5.1	4	3.6	4	5.1	1

[Z]= Castellanos *et al.* (2000).

Foliar analysis

The effect of the application of compost and wheat straw on the nutritional content in olive trees is shown in Table 3. The results of the foliar analysis indicate that, in 2018, with the application of the C+P treatment, the plant leaves showed an increase in most of the nutrients analyzed as N, P, K, Ca, Mg, Na Fe and Zn, with the exception of the content of S, Mn and Cu which decreased. In 2019, the content of nutrients in the leaf did not show differences with respect to the previous year. Raviv *et al*. (2004-2005), mention that compost contains considerable amounts of nutrients that can supplement plant nutrition, this depends on the type of compost since in turn they depend on the different raw materials used, so it cannot be taken as a rule.

The results of the nutritional levels obtained in the foliar analysis in the laboratory in both treatments (T and C+P) in the two years of evaluation (Table 3), indicate that the trees did not present nutritional deficiencies in the content of N, K, Ca, Mn, S, fe, Zn, Mn and B (Fernandez, 2001). The low level of P in the soil was reflected in its content in the leaf, which presented a deficient level as well as the content of Mn and Cu (Table 3). On the other hand, regularly the content of nutrients in the soil is not always related to the foliar analysis of the plant, since potassium deficiencies have been observed in plants established in soils rich in the same element when there is a lack of water for prolonged periods stress (Rallo, 2001).

Table 3. Nutritional content of olive leaves in two treatments in the Manzanilla de Sevilla olive cultivar during the years 2018 and 2019.

Nutriment	Control (T)		C+P		Reference level[z]
	2018	2019	2018	2019	
N (%)	1.9	1.8	2	1.78	1.5-2
P (%)	0.09	0.1	0.1	0.11	0.15-0.25
K (%)	1.07	1.29	1.45	1.23	1-1.2
Ca (%)	1.8	1.99	2.03	1.69	1.5-2.5
Mg (%)	0.2	0.15	0.22	0.15	0.15-0.2
S (%)	0.19	0.21	0.17	0.19	0.1-0.2
Na (%)	0.19	0.06	0.24	0.08	<0.2
Fe (ppm)	121	134	190	104	80-130
Zn (ppm)	24	22.5	29	19.4	15-30
Mn (ppm)	40	60.8	36	48.5	50-130
Cu (ppm)	8	7.09	7	8.4	8-40
B (ppm)	34	42.8	34	47.4	20-70

Sampling date: July 4, 2018 and July 11, 2019; [z]= Fernández (2001).

Humidity of soil

The soil moisture content during the evaluation period is shown in Table 4, where it was observed that there were no statistically significant differences between the T and C+P treatments. However, there were statistical differences between the two depths of the soil (Table 4). Even when there were no differences between treatments. The use of amendments such as manure or compost favor the infiltration process and increase the retention of water and stability of aggregates (Trueba, 1996; Seguel *et al*., 2003).

The factors that influenced the result obtained are, firstly, the efficient management of irrigation water carried out by the cooperating producer, avoiding deficiencies of soil moisture during the evaluation period, on the other hand, the presence of live or cut and spread weeds on the soil surface in both treatments, which covered and protected the soil, preventing the solar rays from evaporating the humidity. In this regard, Shaxson and Barber (2005) mention that plant covers reduce water evaporation due to an improvement in surface structuring, which acts as an anti-evaporation mattress, in addition to being used as ground cover, and being able to be used as fertilizer organic (Arancon *et al*., 2000; Albiach *et al*., 2001; Madejon *et al*., 2001).

The olive tree is a highly drought-tolerant species in relation to other fruit species, although the use of irrigation allows higher yields (Searles *et al*., 2011). This is due to the fact that olive trees have leaves designed to reduce their transpiration, since they have parasolate hairs, also called peltate scales, which are found both on the upper side and on the underside of the leaves, although in the latter in greater proportion and cover the stomata (Barranco *et al*., 2008).

Table 4. Soil moisture content at two treatments and two depths (kPa) in olive trees in the Manzanilla de Sevilla cultivar during 2018 and 2019.

Treatment	Soil depth (cm)	Soil moisture (kPa)
T	40	17.1a[z]
C+P	80	16.8a
T	40	15.4b
C+P	80	14.1b

[z]= means with the same letter are statistically equal (DMS 5%).

Yield

The yields in both treatments are presented in Table 5. The application of the C+P treatment did not statistically affect the yield of the olive fruits and was statistically equal to the control in both years of evaluation. In 2019 the yields obtained by both treatments were more than 100% higher than the yields obtained in 2018, but without statistical differences. These results were due firstly to the phenomenon of alternation (Lavee and Avidan, 1994; Rallo *et al*., 1994) that occurs in the production of the olive tree and secondly, to the larger plant size of the orchard in 2019 with respect to the previous year, which leads to a greater vegetative crown of the tree and consequently greater production capacity.

Table 5. Olive yield in the Manzanilla de Sevilla variety during the years 2018 and 2019.

Treatment	(kg tree^{-1})		(t ha^{-1})	
	2018	2019	2018	2019
T	41.7a[z]	108a	8.3	21.6
C+P	49.4a	118a	9.9	23.7

[z]= means with the same letter are statistically equal (DMS 5%).

Quality

The fruit quality parameters (weight, diameter, length of fruit and pulp-seed ratio) (Table 6) did not show statistical differences between treatments in the two years of evaluation. The application of the C+P treatment did not affect the quality of the fruit with respect to the control. In 2018 the value of all the quality parameters was higher than in 2019 and consequently there was a marked increase in the number of fruits per plant, which caused greater competition for the assimilates produced by the plant and consequently a reduction in the size of the fruits.

Research conducted by Regni *et al*. (2016) reported that applications of compost (130 kg tree^{-1}) from pruning residues and milling residues in the extraction of olive oil increased fruit yield, although without significant difference and did not affect the characteristics of the fruit.

Table 6. Fruit weight, fruit diameter, fruit length and seed pulp ratio in olives of the Manzanilla de Sevilla olive cultivar in 2018 and 2019.

Treatment	Fruit weight (g)		Fruit diameter (cm)		Fruit length (cm)		Relationship pulp/seed	
	2018	2019	2018	2019	2018	2019	2018	2019
T	3.8a^z	3.5a^z	1.7a^z	1.4a^z	2.2a^z	1.8a^z	3.9a^z	3.8a^z
C+P	3.7a	3.5a	1.7a	1.4a	2.2a	1.8a	3.8a	3.8a

^{z}= means with the same letter are statistically equal (DMS 5%).

In this regard Burge *et al*. (1987); Costa *et al*. (1995) mention that the increase in fruit load is accompanied by a decrease in the average weight of the fruit. On the other hand, the fruit load, in trees exposed to the same environmental conditions, is the main factor that modulates growth and, therefore, the final size of the fruit (Lavee and Wodner, 2004).

Conclusions

The application of compost and wheat straw, for at least two years, improved the physical and chemical properties of the soil with the exception of the salinity content and slightly increased the foliar nutritional content in the olive trees, but not so the yield and quality of the fruit with respect to the control and neither the moisture content in the soil.

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