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Productivity and Fruit Quality Influenced by Bioestimulant in Olive under Hot and Arid Environment of Mexico

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Authors' contributions

This work was carried out in collaboration among all authors. Authors RLGC, RMD and ALC designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors RLGC and MJVR managed the analyses of the study and managed the literature searches. Authors FRC and RLGC wrote and edited the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Actually modern fruit trees physiology is focused on the stimulation of plant cell development and fruit production using bioestimulant. This study evaluated the effect of bioestimulant 'Engordone' under two doses (0.5 and 1.0 L ha^{-1}) and two times (pea-size fruit and 28 days later) in olive tree cv Manzanilla under hot and arid environment of Mexico. The experiment was carried out during 2018 and 2019 at National Research Institute for Forestry, Agriculture and Livestock (INIFAP) in the Experimental Station Coast of Hermosillo, Sonora, Mexico. The experiment was carried out on olive tree of eight years old, planted at distance of 10 x 5 m (200 trees ha^{-1}) and under drip irrigation system. The experiment was analyzed using a randomized complete block design and four replications. The variables evaluated were olive yield, classification by size and fruit

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characteristics (fruit weight and pulp-pit ratio). The results showed that bioestimulant application had little effect on olive yield which increased the yield by 14.1 and 6.5% in 2018 and 2019, respectively compared to untreated trees, but without statistical difference. Fruit characteristic were no affected by treatments. Only the percentage of non-marketable fruit was statistically (P<0.05) reduced in the first year. Finally, new biostimulants and times of application are necessary to carried out to improve the size of table olives.

Keywords: Bioestimulant; fruit quality; Olea europaea L; olive yield.

1. INTRODUCTION

The olive (*Olea europaea* L.) was native to Asia Minor and spread from Iran, Syria and Palestine to rest of the Mediterranean basin 6000 years old. It is among the oldest cultivated trees in the world [1]. Currently, olive cultivation is associated with several countries of the Mediterranean Sea basin and plays an important role in the diets, economies and cultures of the region. However, olive production has extended beyond this region to South and North America, South of Africa and Australia. The olive is considered as dry climate crop, capable of sustaining long periods of water deficit and with a moderate tolerance to saline soils, because of which it has been successfully cultivated in saline soils where other fruit trees cannot grow [2,3].

The production of olive in the world reaches an annual average of about 12 million tons of olive of which 90% is dedicated to obtain oil and only 10% is consumed processed for table olive. The major olive oil producing country is Spain with 30% and together with Italy, Greece and Turkey produce about 90% of world production [4]. The trend of consumption of olive oil in the world has increased to 97% in the last 20 years [5]. In Mexico the acreage planted with olive trees in the year 2018 was 7 406 hectares. National production of olive in this year was low only 10 698 tons with production value of 7.8 millions of dollars [6]. On the other hand, it is estimated that around 40% of olive production is destined for table olive and the majority was exported to the United States as fresh fruit being Manzanilla and Mission the main cultivars [7].

The application of growth regulators is a common practice to increase yield and quality in many fruit species [8]. Applications of gibberellic acid and naphthaleneacetic acid during the fruit set period to increase the size of olives have given satisfactory results [9,10,11].

New bioestimulant fertilizers are nowadays used to enhance nutrient uptake and stimulate stress-related tolerance mechanism. They could be defined as products containing substances and or micro-organism whose function when applied to plants or rhizosphere is to stimulate natural processes that enhance flowering, plant growth, fruit set, crop productivity, and nutrient use efficiency and are able also to improve the tolerance against a wide range of abiotic stressors [12,13].

Actually modern fruit trees physiology is focused on the stimulation of plant cell development and fruit production using bioestimulant. Foliar and soil applications with different types of biostimulants during flowering and fruit set in olive trees have increased fruit set, productivity and fruit quality [14,15,16,17], increase in oil content and quality [15,16], also improved fruit quality by advancing and uniforming fruit ripening [15,18].

Currently, in Mexico there are few studies on agronomic management in olive production and the acreage has not been increased despite the proximity with United States which is the main importer of olive in the world [5]. The profitability of table olives is given by the yield and fruit quality mainly by the fruit size. The present study had the objective to evaluate different doses and times of a biostimulant on olive tree cv Manzanilla under hot and arid environment of Mexico.

2. MATERIALS AND METHODS

2.1 Description of Experimental Site

The experiment was carried out during two consecutive years 2018 and 2019 at National Research Institute for Forestry, Agriculture and Livestock (INIFAP) in the Experimental Station Coast of Hermosillo, Sonora, Mexico (30°42’ 55’’ N, 112°21’28’’ W and 200 meters above sea level (masl). The annual evaporation ranges from 2 400 to 2 700 mm. Annual mean temperature is 22°C, being January, the coldest month with 4.6°C and July is the month with the higher temperature with 40.2°C. Chilling hours recorded during last 10 years of 276 hours according to Damotta method [19]. The soil was sandy with pH 7.96 and electrical conductivity of 1.22 dSm^{-1}

2.2 Treatments Applied

This experiment included four treatments as follows:

- T1 Two applications of bioestimulant, the first when the fruit reached the size of a pea with a dose of (1.0 g L^{-1}) and the second application at 28 days later in a dose of (0.5 g L^{-1}).
- T2 One application of bioestimulant when the fruit reached the size of a pea with a dose of (1.0 g L^{-1})
- T3 One application of bioestimulant to 28 days after that the fruit reached the size of a pea with a dose of (1.0 g L^{-1})
- T4 Control (Untreated trees)

The bioestimulant used in this experiment was Engordone® (Lida Plant Research) which promotes the synthesis of proteins and enzymes that activate cell growth and division and what contains (P, K, Bo, Mn, Mo, Zn, growth regulators as auxins, gibberellins and cytokinins, proteins, carbohydrates, vitamins A, B1, B6 y B12 and antioxidants [20]. During 2018 the first Engordone application was done on April 25 while that in 2019 was April 30. The foliar applications were made to dropping point with a gasoline-powered mist blower (Port 423, Solo Sindelfingen, Germany). The amount of water used was 6.0 per tree.

2.3 Orchard Management

The experiment was carried out on olive orchard cultivar Manzanilla of eight years old, planted at a spacing of 10 x 5 m (having 200 trees ha^{-1}) and under drip irrigation system. The annual volume of water applied was 8 200 m^3 ha^{-1}. In each year orchard olive was fertilized with compost at rate of 80.0 kg per tree (16.0 tons ha^{-1}) during February and with ammonium nitrate (60 kg ha^{-1}) during the postharvest period. The olive harvest was done manually on July 20, 2018 and August 18, 2019. Other agronomic practices were done in accordance to commercial recommendations [21].

2.4 Measurement Variables and Statistical Analysis

The following measurements were taken: 1). Yield, at harvest all olive fruit were collected and weighed to obtain the production per tree, 2). Classification by fruit size, all harvested fruits were classified by size using a commercial sorting band into 4 categories in accordance with [22] as follows: Small size (280-320 fruits kg^{-1}), medium size (200-240 fruits kg^{-1}), large size (160-180 fruits kg^{-1}) and petite (rejected for exportation) and fruit characteristics (fruit weight and pulp-pit relation) were evaluated taking a random sample of 100 fruit for each tree.

This experiment was analyzed using a randomized complete block design and four replications. The experimental plot was one tree. Means were compared by least significant difference test (LSD) at 5% level of significance. The analysis of variance and means tests were analyzed using the UANL computer package program [23].

3. RESULTS AND DISCUSSION

3.1 Olive Yield

The results in Table 1 indicate that there were statistical differences among treatments in olive yield in both years. During 2018 the olive yield varied from 34.5 to 39.5 kg $tree^{-1}$ while, in 2109 varied from 91.5 to 100.8 kg $tree^{-1}$. It is important to mention that although without statistical difference among treatments the higher olive yield was obtained with T1 and the lower yield was obtained with T4 in both years. The notable difference in olive yield between years can be explained by the alternate bearing in production which was "off" in 2018 and "on" in 2019, good climatic conditions as such chilling hour accumulation and rainfall during winter. Another answer, is that the trees are one year older which is important in young plantations due to its greater production capacity and finally that in 2018 the production pruning carried out in winter was minimal and only the suckers on the trunk were eliminated.

Although without statistical difference in 2018 the trees that were applied with biostimulant had an average increase in yield of 14.1% which represents 4.8 kg $tree^{-1}$ of olive fruits, while in 2019 season the increase was 6.5% which represents 6.0 kg $tree^{-1}$ compared to the untreated trees.

The small increase in olive yield obtained in this experiment was similar with those reported by other researchers using different bioestimulant and olive cultivars [15,16,24,25]. Tone, [26] reported that applications of different doses of the biostimulant Agrocimax Plus on Sevillano olive cultivar a linear response on fruit set and yield was observed where the best treatment increased the fruit yield by 46.7% with respect to the control treatment. Mayi, [27] found that the response of biostimulants application on fruit yield was different between olive cultivars. Also, the crop management such as irrigation and nutrient content can affect the bioestimulant response in olive tree [25].

The high content of minerals and vitamins as well auxins, gibberellins and cytokinins in the biostimulant are attributed to the increments on the amounts of metabolites synthesized by the plant which in turn accelerate plant growth which are enable to absorb minerals by its root system and thus reflected on the fruit yield [28].

3.2 Fruit Size Distribution

In Tables 2 and 3 are shown the olive fruit size distribution for 2018 and 2019 season. During 2018 season only in petite fruit there were statistical differences ($P< 0.05$) among treatments. This fruits are rejected for export due to their insufficient size (<9/16). The percentage of small fruit varied from 16.0 to 19.0, medium fruit from 46.7 to 52.9, large fruit from 29.3 to 33.9. For petite fruit T4 obtained the highest value with 3.1% of fruits rejected for export, followed by T1, T2 and T3 with values ranged from 1.6 to 2.0% without statistical difference between them. By other side, in 2019 There were not statistical differences among treatments in neither fruit size. The distribution percentage of small fruit varied from 30 to 34%, medium fruit from 46.7 to 52.9, large fruit from 29.3 to 33,9 and petite fruit from 6.5 to 9.2. The results obtained in olive fruit size distribution are in accordance with those reported by [29] in 'Manzanilla' under similar agro environmental conditions where the profitability of artificial pollination in a year with high yield was tested.

The distribution of harvested fruits by size showed notable differences between years and did not show a clear trend among treatments. The percentage in all treatments per year and fruit size obtained in 2018 was characterized by lower percentage of small fruit (17.4 vs 31.7), similar percentage of medium fruit (49.4 vs 43.4), higher percentage of large fruit (31.1 vs 17.0) and lower percentage of petite fruits (2.1 vs 7.7) compared to 2019. These differences in the distribution of the fruit size between years can be explained by the higher yield obtained in 2019, which causes more competition between fruits within the same shoot by assimilates produced by the plants and is consequently reflected in a lower weight and size of the fruit [30,31].

In some years the price of the small size olive of 'Manzanilla' in the United States market is 33% lower compared to medium and large size olives [32]. The agronomic management carried out by the olive grower to improve fruit size and reduce small olives are to delay the harvest as far as possible, increase fertilization especially nitrogen, and improve the use of irrigation and, finally the use of biostimulants applied during the cell elongation stage of fruits.

3.3 Fruit Characteristics

There were not statistical differences among treatments in fruit weight and pulp-pit ratio in both years (Table 4). Fruit weight varied from 3.80 to 4.03 and from 3.49 to 3.65 grams per fruit during 2018 and 2019, respectively without clear trend among treatments. By other side, in 2018 pulp-pit relation values varied from 4.35 to 4.62, while that in 2019 pulp-pit ratio values varied from 4.54 to 4.68 although, without statistical difference the highest value was in T1 in both years. In general terms, a 9.8% increase in fruit size was observed in 2018, while a 2.8% increase in the pulp-pit ratio was recorded in 2019. These differences can be explained by the level of fruit load between years.

Table 1. Olive yield in the evaluation of the bioestimulant (Engordone) applied on olive trees cv Manzanilla during 2018 and 2019 seasons

Treatments	Yield (kg tree^{-1})	
	2018	**2019**
T1	40.5 ^{a}	100.8 ^{a}
T2	36.5 ^{a}	93.4 ^{a}
T3	39.5 ^{a}	98.4 ^{a}
T4	34.0 ^{a}	91.5 ^{a}
Significance	N.S.	N.S.
CV (%)	12.5	11.2

Means followed by the same letter in a column do not differ significantly (LSD 0.05) N.S. Non-Significant

Table 2. Olive fruit size distribution in the evaluation of the bioestimulant (Engordone) applied on olive trees cv Manzanilla during 2018 season

Treatments	Size Distribution (%)			
	Small	Medium	Large	Petite
T1	19.0 a	49.6 a	29.4 a	2.0 a
T2	16.0 a	52.9 a	29.3 a	1.8 a
T3	16.2 a	48.3 a	33.9 a	1.6 a
T4	18.3 a	46.7 a	31.9 a	3.1 b
Significance	N.S.	N.S.	N.S.	*
CV (%)	7.2	6.4	5.7	8.1

*Means followed by the same letter in a column do not differ significantly (LSD 0.05) * Significant at (P≤0.05). Small size (280-320 fruits kg^{-1}), medium size (200-240 fruits kg^{-1}), large size (160-180 fruits kg^{-1}) and petite (fruits rejected for exportation <9/16). Adaptation from [22]*

Table 3. Olive fruit size distribution in the evaluation of the bioestimulant (Engordone) applied on olive trees cv Manzanilla during 2019 season

Treatments	Size Distribution (%)			
	Small	Medium	Large	Petite
T1	30.0 a	44.5 a	19.0 a	6.5 a
T2	31.0 a	44.1 a	17.5 a	7.4 a
T3	34.0 a	42.8 a	15.2 a	8.0 a
T4	32.4 a	42.2 a	16.2 a	9.2 a
Significance	N.S.	N.S.	N.S.	N.S.
CV (%)	14.2	9.8	10.9	10.2

Means followed by the same letter in a column do not differ significantly (LSD 0.05) N.S. Non-Significant; Small size (280-320 fruits kg^{-1}), medium size (200-240 fruits kg^{-1}), large size (160-180 fruits kg^{-1}) and petite (fruits rejected for exportation <9/16). Adaptation from [22]

Table 4. Fruit characteristics in the evaluation of the bioestimulant (Engordone) applied on olive trees cv Manzanilla during 2018 and 2019 seasons

Treatments	Fruit Weight (g)		Pulp-Pit Ratio	
	2018	2019	2018	2019
T1	3.90 a	3.65 a	4.62 a	4.68 a
T2	4.00 a	3.60 a	4.35 a	4.53 a
T3	4.03 a	3.49 a	4.48 a	4.62 a
T4	3.80 a	3.60 a	4.40 a	4.54 a
Significance	N.S.	N.S.	N.S	N.S.
CV (%)	10.2	7.2	12.2	9.2

Means followed by the same letter in a column do not differ significantly (LSD 0.05) N.S. Non-Significant

The values found in fruit weight and pulp-pit ratio are similar to those reported by previous research in 'Manzanilla' under similar agro environmental conditions [33]. The little or no response of the application of biostimulants to improve olive fruit quality is in accordance with that reported by [17,18] using different types of biostimulant on different olive tree varieties. Olive fruit size and pulp-pit ratio are important characteristics for table olive production.

4. CONCLUSION

From the results of this study, it can be concluded that Engordone application on olive tree 'Manzanilla' had little effect on fruit yield, and fruit weight and fruit pulp-pit ratio were not affected. Only the percentage of non-marketable fruit was statistically reduced in the first year.

New biostimulants and times of application are necessary to carried out to improve the size of table olives.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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