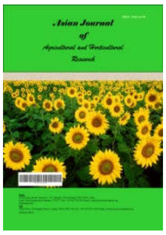

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Preliminary Evaluation of Olive (*Olea europaea* L.) Cultivars in Northwest and Central of Mexico

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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

A strategy to improve productivity in olive orchards is the evaluation of cultivars that respond better to the environmental growing conditions The objective of this experiment was to evaluate the yield potential and oil quality of five olive cultivars (Arbequina, Coratina, Manzanilla, Arbosana and Mission) in two regions of Mexico. The experiment was carried out during two consecutive years 2018 and 2019. At Northwest Region the five olive cultivars were planted in 2013 at a spacing of 10 x 5 m (having 200 trees ha^{-1}) and Central Region olive cultivars were planted in 2013 at spacing of 6 x 6 m (278 trees ha^{-1}) and both locations under drip irrigation systems. The variables evaluated were: yield, fruit weight, oil content and oil quality (acidity, peroxide value and absorbance K232 and K270). The experiment was analyzed using a randomized complete block design with four replications.

Our results showed high differences between locations, Arbequina was the cultivar with the highest yield at the fifth and sixth years of planting with an average of 48.8 kg $tree^{-1}$ at Northwest Region

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and only 15.5 kg tree^{-1} at Central Region. The cultivar with the highest oil content in the Northwest Region was Manzanilla with an average of 12.3% and the lowest for Arbequina with only 9.3%, while at Central Region the cultivar with the highest oil content was Coratina with 20.2% and the lowest in Manzanilla with 16.1%. Extra virgin olive oil was obtained in all the cultivars in both locations according to chemical analysis. Finally, it is necessary to continue with the evaluation of other varieties with resistance to high temperatures at Northwest Region and resistance to frost at Central Region.

Keywords: Olea europaea L; varieties; olive yield; oil quality.

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 de Mediterranean Sea basin and plays an important role in the diets, economies and cultures of the region. However, has extended beyond this region to South and North America, South of Africa and Australia. The olive is considered a 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 about 12 million tons of olive of which 90% is dedicated to obtain oil and only 10% is consumed processed for table olive. The main country producer of olive oil 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 for 2018 year was of 7 406 hectares of which about 72% are in productive stage. National production of olive in this year was low only 10 698 tons due climatic problems, such as lack of winter cold and high temperatures during the flowering (>34°C). The production value was of 7.8 millions of dollars [6]. On the other hand, it is estimated that around 60% of olive production is destined for oil production and 40% to the production of table olives.

In Northern of Mexico the main olive cultivars are Manzanilla and Mission which are dedicated to the oil extraction and table olive production [7]. By other side, news olive orchard in Central Mexico are established with Arbequina, Coratina and Local Selection cultivars. Olive growers are using high density and those plantations are dedicated for olive oil production exclusively [8]. Also, experimental plots are planted with Hidrocalida cultivar, which was the first and unique olive cultivar released in Mexico at Nacional Research Institute for Forestry, Agriculture and Livestock (INIFAP) by [9].

The production of olive oil in Mexico is very low, only 2,500 tons per year, while consumption is 8,200 tons per year. In the Northwest and North of Mexico 85% of olive oil is produced and in these regions the potential productivity is higher compared to Central Mexico [8,10].

Previous research under desert conditions in Northwestern of Mexico have identified Carolea and Barnea as olive cultivars with high yield and good oil content and quality [11] and new varieties are being tested in Central Mexico under cold conditions and high altitude [8].

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. Among the strategies for productive improvement of olive orchard is the evaluation of cultivars that respond better to the environmental growing conditions. The objective of this experiment was to evaluate the yield potential and oil quality of five olive cultivars in the Northwest and Central of Mexico.

2. MATERIALS AND METHODS

2.1 Genetic Material and Description of Experimental Site

The experiment was carried out during two consecutive years in 2018 and 2019. Five olive cultivars (Arbequina, Coratina, Arbosana, Mission and Manzanilla) and two regions (Northwest and Central Mexico) were tested. Climatic characteristics and soil properties in both regions are shown in Table 1.

Table 1. Climatic characteristics and properties soil in Northwest and Central regions in Mexico

Parameters	Northwest Region	Central Region
Location name	Caborca, Sonora	San Miguel Allende, Guanajuato
Latitude	30° 42' 55'' N	20° 54' 55 W
Longitude	112° 21' 28''	100° 44' 38 W
Altitude	40 m.a.s.l.	1923 m.a.s.l.
Rainfall	80 mm	562 mm
Annual means temperature	22.4°C	18.5°C
Coldest month	January (4.6° C)	January (8.0°C)
Hottest month	July (40.2°C)	May (31.2°C)
Soil texture	Sandy	Sandy Loam
PH	7.9	7.2
Electrical conductivity	3.4 dSm^{-1}	1.22 dSm^{-1}

Sources: [8,10,12]

2.2 Orchard Management

At Northwest Region the five olive cultivars were planted in 2013 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 6 200 m^3 ha^{-1}. In each year, olive cultivars were fertilized with compost at rate of 35.0 kg per tree during February and with ammonium nitrate (30 kg ha^{-1}) during the postharvest period. There were no disease problems and for the control of the olive fly (*Bactrocera Oleae*) three applications of Spinosad (1.0 L ha^{-1}) were realized. Other agronomic practices were done in accordance to commercial recommendations [12]. At Central Region olive cultivars were planted in 2013 at spacing of 6 x 6 m (278 trees ha^{-1}) and under drip irrigation systems. The water applied per season was about 2 900 m^3 ha^{-1}. Olive cultivars were fertilizer with 18-18-18 three times a year. The main foliage disease that occurred was Peacock Spot (*Spilacea oleagina*) which has been controlled with Tebuconazole (0.5 L ha^{-1}) or Copper Sulfate 50% (2.0 kg ha^{-1}) and minor pest problems were presented as Glyphodes (*Margaronia unionalis*). Other management practices were carried out in accordance to the recommended by Ávila-Escobedo et al. [8].

A single pruning conduction was carried out at planting time on all cultivars in both regions, this pruning consisted of eliminating secondary twigs of less 80 cm leaving anything over this threshold to grow freely. The olive harvest was done manually during mid-September and end October at maturity index of 2.5 to 3.5 which correspond when more than half of the fruit has a red or purple skin and usually used for most olive oil cultivars [13].

2.3 Measurement Variables

The following measurements were taken: 1). Yield, at harvest all olive fruit were collected and weighed to obtain the production per tree, 2). Fruit weight taking a random sample of 50 fruits for each tree, 3). Oil content was determined by extracting the oil in a press mill (Olerossi) with an extraction capacity of 80 kg hou^{-1} at Northwest Region and with an oil mill with a continuous system (Olio Mio) with an extraction capacity of 250 kg $hour^{-1}$ at Central Region, 3). Quality oil (acidity (%oleic acid), peroxide value (meq O_2 kg oil^{-1}) and Absorbence K 232 and K 270). These parameters were determined using chemical analysis according to the methodology described by AOAC [14].

2.4 Statistical Analysis

This experiment was analyzed using a randomized complete block design and four replications. The experimental plot was one tree. Means were compared by the 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 [15].

3. RESULTS AND DISCUSSION

3.1 Olive Yield

Table 2 are shown the olive yield between the different cultivars in both locations and years. At Northwest Region there were statistical differences (P<0.01) among cultivars and years. In 2018 the cultivar that presented the highest yield was Arbequina with 32.2 kg $tree^{-1}$ and the lowest in Mission with 12.4 kg $tree^{-1}$, in the rest of the cultivars the yield varied from 19.0 to 24.0 kg tree^{-1} without statistical difference between them. In 2019 the same trend was obtained as the previous year, because Arbequina presented the highest yield with 65.4 kg tree^{-1} and the lowest yield in Mission with 14.1 kg tree^{-1} and the rest of the cultivars the yield varied from 25.2 to 39.4 kg tree^{-1} without difference statistics between them. At Central Region there were statistical differences($P<0.05$) between cultivars and years. In 2018 Arbequina and Coratina cultivars recorded the highest yields with 13.8 and 12.2 kg tree^{-1} respectively, while in the rest of the cultivars the yield varied from 6.1 to 8.0 kg tree^{-1} without statistical difference between them. In 2019 the highest yields were obtained in Arbequina and Coratina 17.2 and 14.3 kg tree^{-1}, respectively, while the lowest yield was obtained for Mission with 11.2 kg tree^{-1}, although without statistical difference to Arbosana and Manzanilla.

At both locations and years, Arbequina showed the highest olive yield. The high productivity of Arbequina and the difference in the yield among cultivars are in accordance with other researchers [11,16,17,18,19]. The higher yield in Arbequina the first years can be explained to the earliness and better adaptation to agroclimatological conditions. The differences found in this study among cultivars indicate a favorable situation for the selection of cultivars for regions different from Mexico and further is proving effective from the point of view of improving productivity.

The average yield between cultivars in the fifth and sixth year of planting at Northwest Region was 22.3 and 34.9 kg tree^{-1} for 2018 and 2019 respectively, while in the Center Region was only 9.2 and 12.9 kg tree^{-1} for the same years. In Northwestern Region there is a greater yield potential for the olive tree production due to better weather conditions such as well-defined summers and winters, free pest mainly olive fly, although in certain years high temperatures in flowering (>32°C), low relative humidity (<40%) and hot winds cause problems in pollination and fruit set [12]. On the other hand, the Central Region is located outside the olive-producing belt (from 30° to 45° Latitude North and South) which is compensated by the altitude (1923 m.a.s.l.) The main problem for olive production in this region is frost damage before and during flowering and hail damage during fruit development.

3.2 Fruit Weight

The results in Table 3 indicate that there was a statistical difference ($P<0.01$) in fruit weight (average of two years) among cultivars in both locations. At Northwest Region the highest fruit weight was obtained in the Manzanilla and Mission cultivars with 4.67 and 4.00 grams per fruit respectively, followed by Coratina with 3.60 grams per fruit, while the lowest fruit weight was obtained in the Arbequina and Arbosana with 1.52 and 1.80 grams per fruit, respectively.

At Central Region, the highest fruit weight was for the cultivars was for Manzanilla and Mission with 4.20 and 3.90 grams per fruit, followed by Coratina with 3.82 grams per fruit and the lowest weight was for the Arbequina and Arbosana cultivars with 1.60 and 1.75 grams per fruit, respectively. Manzanilla and Mission cultivars for their good fruit size are dedicated for the production of table olives or a good option as cultivars with dual purpose. Fruit weight is influenced by agronomic management and load level on trees. The values recorded on fruit weight among cultivars are similar to those described by Civantos [4], Grijalva-Contreras et al. [7], Reza et al. [16].

3.3 Oil Content

Table 4 are shown the oil content among different cultivars in both locations and years. At Northwest Region there were statistical differences ($P< 0.01$) in 2018 and ($P< 0.05$) in 2019. In the first year, Manzanilla and Coratina cultivars had the highest oil content with 12.5 and 11.4%, respectively and lowest oil content was obtained in Arbequina with 9.5% but being statistically equal to Mission and Arbosana. In the second year, Manzanilla, Coratina and Mission cultivars obtained the highest oil content with 12.0, 11.2 and 11.0%, respectively and the lowest content was recorded in Arbequina with only 9.2%. On the other hand, at Central Region there were statistical differences ($P< 0.05$) in the oil content in both years. In 2018, Manzanilla cultivar obtained the highest oil content with 21.4 and the lowest in Manzanilla with 16.3%, although statistically equal to Arbosana and Arbequina. In 2019, Coratina, Arbosana and Mission cultivars were the ones with the highest oil content with 18.9, 18.2 and 17.9%, respectively, and the lowest for Manzanilla and Arbequina with 15.9 and 17.1%, respectively.

At Nortwest Region and considering olive yield, oil content and plant density for each year was obtained that Arbequina with the highest productivity with 614 and 1203 kg of oil ha^{-1} for 2018 and 2019 year. On other side at Central Region were Coratina and Arbequina who recorded the highest productivity with 723.6 and 815.0 kg of oil ha^{-1}, respectively. These values are similar to those reported by Grijalva-Contreras et al. [7].

It is important to emphasize that in Northwest Region, the Manzanilla cultivar obtained the highest percentage of oil content with an average of 12.3%, while the Central Region recorded the lowest oil content with 16.1%. Previous studies by Grijalva-Contreras et al. [11] and Contreras et al. [7] on evaluations of olive cultivars carried out in Mexico have shown that under hot and arid environments the best cultivars for oil production has been Barnea and Carolea con 19.2 and 17.5% of oil content.

Finally, the percentage of oil content obtained among cultivars Nortwest Region was much lower than those found by most studies [16,17,19,20,21,22]. The oil content is determined mainly by varieties, harvest date [21] and the difficulty in its extraction [20]. The low percentage of oil content in this location can be explained to the high temperature (>40°C) during the ripening process of the fruit and the

Table 2. Olive yield in the evaluation of five olive cultivars in two regions of Mexico during 2018 and 2019 years

Cultivars	Northwest Region Yield (kg tree^{-1})		Central Region Yield (kg tree^{-1})	
	2018	2019	2018	2019
Arbequina	32.2 ^{a}	65.4 ^{a}	13.8 ^{a}	17.2 ^{a}
Coratina	24.0 ^{b}	39.4 ^{b}	12.2 ^{a}	14.3 ^{ab}
Manzanilla	19.0 ^{b}.	30.4 ^{b}	6.1 ^{b}	12.1 ^{bc}
Arbosana	24.0 ^{b}	25.2 ^{b}	6.2 ^{b}	10.0 ^{bc}
Mission	12.4 ^{c}	14.1 ^{c}	8.0 $_{b}$	11.2 ^{c}
Significance	**	**	*	*
C.V. (%)	10.4	13.5	26.3	18.5

*Means followed by the same letter in a column do not differ significantly (LSD 0.05). *Significant at (P≤0.05) and ** Significant at (P≤0.01)*

Table 3. Fruit weight in the evaluation of five olive cultivars in two regions of Mexico during 2018 and 2019 years

Cultivars	Northwest Region Fruit Weight (g)^{z}	Central Region Fruit Weight (g)^{z}
Arbequina	1.52 ^{c}	1.60 ^{c}
Coratina	3.60 ^{b}	3.82 ^{b}
Manzanilla	4.67 ^{a}	4.20 ^{a}
Arbosana	1.80 ^{c}	1.75 ^{c}
Mission	4.00 ^{a}	3.90 ^{a}
Significance	**	**
C.V.(%)	6.5	8.3

*Means followed by the same letter in a column do not differ significantly (LSD 0.05). ** Significant at (P≤0.01).*
^{z}Fruit weight are average of two years

Table 4. Oil content (%) in the evaluation of five olive cultivars in two regions of Mexico during 2018 and 2019 years

Cultivars	Northwest Region		Central Region	
	2018	2019	2018	2019
Arbequina	9.5 ^{c}	9.2 ^{c}	18.2 ^{bc}	17.1 ^{b}
Coratina	11.4 ^{ab}	11.2 ^{ab}	21.4 ^{a}	18.9 ^{a}
Manzanilla	12.5 ^{a}	12.0 ^{a}	16.3 ^{c}	15.9 ^{b}
Arbosana	10.4 ^{bc}	10.0 ^{bc}	17.5 ^{bc}	18.2 ^{a}
Mission	10.8 ^{bc}	11.0 ^{ab}	19.1 ^{b}	17.9 ^{ab}
Significance	**	*	*	*
C.V. (%)	4.9	6.2	6.8	8.2

*Means followed by the same letter in a column do not differ significantly (LSD 0.05). *Significant at (P≤0.05) and ** Significant at (P≤0.01)* different mills used in the oil extraction. Nissim et al. [23] reported that high temperature environment decreased oil content in Koroneiki and Souri olive cultivars by 15 and 8.0% respectively.

3.4 Oil Quality

3.4.1 Acidity and peroxide value

These oil quality parameters were recorded only in 2018 year. The acidity of olive oil is considered a basic characteristics of the quality. The results reported in Table 5 show that there were no statistical differences between cultivars in both locations. At Northwest Region the values ranged from 0.35 to 0.50 while that, at Central Region the values ranged from 0.24 to 0.32. The percentage of acidity obtained in all cultivars correspond an extra virgin oil. An extra virgin olive oil must have an acidity (% oleic acid) < 0.80% [24].

Peroxide value is used as an indicator to reveal enzymatic and oxidative deterioration in oil. It´s also used to monitor production problem, which occur after harvest and during processing (Barone et al., 1994). The results shown in Table 5 indicate that there were statistical differences ($P< 0.01$) only at Nortwest Region with Arbosana and Manzanilla with the highest values with 13.2 and 12.8 meq O_2 kg oil^{-1}, respectively and the lowest value e Arbequina with 8.9 meq O_2 kg oil^{-1}, At Central Region the values ranged from 12.8 to 15.2 meq O_2 kg oil^{-1}. Also the peroxide value obtained in all cultivars correspond an extra virgin oil. An extra virgin olive oil must have a peroxide value (< 20 meq O_2 kg oil^{-1}) [24]. The differences in acidity and peroxide value found among cultivars are in accordance with that reported by Grijalva-Contreraset al. [11], Al-Maaitah et al. [21], Freihat et al. [25].

3.4.2 Absorbency ultraviolet K232 and K270

Olive oil analysis in UV spectrophotometer provides information on the quality of the oil, its state of conservation and modifications induced by technological processes (Barone et al.,1994). The ultraviolet absorbance at 232 and 232 showed statistical difference ($P< 0.05$) only at the Central region at 270 nm (Table 6). In this location Mission was the lowest value with 0.08 being statistically different from the rest of the cultivars. The maximum value for K 232 and K270 for extra virgin quality oil are 2.5 and 0.22, respectively. Therefore, the oil obtained from cultivars in both locations can be considered extra virgin. The differences in absorbance value among cultivars are in accordance with that reported by De Oliveira et al. [26].

Table 5. Acidity (%) and peroxide value (meq O_2 kg oil^{-1}) in the evaluation of five olive cultivars in two regions of Mexico during the 2018 year

Cultivars	Northwest Region		Central Region	
	Acidity	Peroxide Value	Acidity	Peroxide Value
Arbequina	0.46	8.9 ^{d}	0.32	13.8
Coratina	0.35	10.4 ^{c}	0.24	15.0
Manzanilla	0.50	12.8 ^{ab}	0.25	15.2
Arbosana	0.42	13.2 ^{a}	0.26	14.4
Mission	0.40	12.4 ^{b}	0.22	12.8
Significance	N.S.	**	N.S.	N.S.
C.V. (%)	12.0	6.5	12.5	15.1

*Means followed by the same letter in a column do not differ significantly (LSD 0.05). N.S. Non significant. ** Significant at ($P≤0.01$)*

Table 6. Absorbency UV (232 nm and 270 nm) in the evaluation of five olive cultivars in two regions of Mexico during the 2018 year

Cultivars	Northwest Region		Central Region	
	232	270	232	270
Arbequina	1.8	0.20	2.0	0.15 ^{a}
Coratina	2.0	0.17	1.9	0.15 ^{a}
Manzanilla	1.9	0.15	2.2	0.14 ^{a}
Arbosana	2.1	0.18	1.9	0.12 ^{a}
Mission	1.8	0.14	2.0	0.08 ^{b}
Significance	N.S.	N.S.	N.S.	*
C.V. (%)	11.6	14.0	10.2	9.1

*Means followed by the same letter in a column do not differ significantly (LSD 0.05). N.S. Non significant. * Significant at ($P≤0.05$)*

The chemical characteristics (acidity, peroxide value, Absorbance to K232 and K270) obtained from the oil of the different cultivars evaluated can initially be classified as extra virgin quality. Olive oil quality is influenced by a great number of factors including the cultivars, fruit maturity stage, pest and disease damage, harvest method, harvest time to milling, oil extraction method, among others [27].

4. CONCLUSION

From the results of this study, it can be concluded that, preliminarily Arbequina represents a good option for the production of olive oil due to its high productivity and precocity in producing for the Northwestern and Central Region of Mexico.

At Northwest Region, olive cultivars obtained higher olive yield but the lower oil content compared at Central Region and the quality of oil obtained in all cultivars in both regions and years due to their percentage of acidity, peroxide value and absorbance are classified as olive oil extra virgin.

It is necessary to continue with the evaluation of other varieties with resistance to high temperatures in the Northwest Region and resistance to frost in the Central Region.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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