Preliminary Evaluation of Olive (*Olea europaea* L.) Cultivars Under Hot and Arid Environment of Mexico

Raúl Leonel Grijalva-Contreras[1*], Rubén Macías-Duarte[1], Arturo López-Carvajal[1], Fabián Robles-Contreras[1], Manuel de Jesús Valenzuela-Ruiz[1] and Fidel Núñez-Ramirez[2]

[1] National Research Institute for Forestry, Agriculture and Livestock (INIFAP) Experimental Station of the Coast of Hermosillo. Pascual Encinas Félix No. 21. Colonia la Manga. Postal Code 83220. Hermosillo, Sonora México.*
[2]Science Agriculture Institute, Autonomous of Baja California University (ICA-UABC). Carretera Delta s/n Ejido Nuevo León. Postal Code 21705. Baja California, México.

.

ABSTRACT

Currently in Mexico there are few studies on agronomic management in olive production. The objective of this experiment was to evaluate eleven olive cultivars for table and oil production (Arbequina, Koroneiki, Arbosana, Kalamata, Barnea, Pendolino, Empeltre, Manzanilla of Sevilla, Carboncella, Frantoio and Cassaliva) under hot and arid environment of Mexico. The experiment was carried out during two consecutive years in 2015 and 2016 at National Research Institute for Forestry, Agriculture and Livestock (INIFAP) in the Experimental Station of Caborca, Sonora, Mexico. The plantation was done on March, 2012 using a density of 100 trees ha^{-1} (10 x 10 m) under drip irrigation system. The parameters evaluated were vegetative parameters, yield, fruit quality and oil content. The experiment was analyzed using a randomized complete block design and five replications. The results showed statistical differences for all parameters evaluated. Arbequina obtained the highest olive yield with 34.5 and 70.3 kg per tree for the first and second year production, respectively and Barnea recorded the highest oil content with 19.2%. Finally, Manzanilla of Sevilla and Barnea varieties represent a good option as double-purpose varieties.

Keywords: Cultivars, desert condition, fruit quality, olive, oil content, yield.

1. INTRODUCTION

The olive (*Olea europaea* L.) is among the oldest cultivated trees in the world. 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, 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 (Benlloch et al., 1991; Isidoro and Aragües, 2006).

* E-mail address: xyz@abc.com.

Commercial production of olive tree in the world is between 30° and 45° North and South latitude. 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 producer country of olive oil is Spain with 30% and together with Italy, Greece and Turkey produce about 90% of world production (Civantos, 2001). The trend of consumption of olive oil in the world has increased to 97% in the last 20 years (COI, 2016).

In Mexico the total planted area with olive trees for 2014 year was of 8 928 hectares of which about 80% are in productive stage. National production of olive in this year was of 27 209 tons with a production value of 11.02 millions of dollars (SIAP, 2014). On the other hand, it is estimated that around 60% of olive production is destined for oil production. In Northern Mexico the main cultivars of olive are “Manzanilla of Sevilla” and “Mission” which are dedicated to the production of table olive and oil, while news plantations of olive in Central Mexico are planted with “Arbequina” cultivar, growers are using high density and those plantations are dedicated for olive oil production exclusively (Ávila-Escobedo et al., 2017). Also, experimental plots are planted with “Hidrocálida” cultivar, which was the first and unique olive cultivar released in Mexico at Nacional Research Institute for Forestry, Agriculture and Livestock (INIFAP) by (Perales et al., 2011).

Previous research on evaluations of olive cultivars carried out in Mexico have shown that under hot and arid environments the best olive variety has been ‘Carolea’ with 9.0 t ha^{-1} of olives, and 1557.5 kg ha^{1} of oil during the first six years of production, it was the cultivar with higher oil content with 17.5%. (Grijalva et al., 2014).

Currently in Mexico there are few studies on agronomic management in olive production, despite the proximity with the United States of America which is the main importer of olive oil 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 present study had the objective to evaluated eleven olive cultivars for table and oil production under hot and arid environment of Mexico.

2. MATERIAL AND METHODS

2.1. Description of experimental site

The experiment was carried out during two consecutive years in 2015 and 2016 at National Research Institute for Forestry, Agriculture and Livestock (INIFAP) in the Experimental Station of Caborca, Sonora, México (30° 42’ 55’’ N, 112°21’28’’W and 200 m above sea level. Annual evaporation ranges from 2 400 to 2 700 mm. Annual means temperature of 22°C, being January, the coldest month 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 (INIFAP, 1985 and Ruiz et al., 2005). The soil was sandy with pH 7.96 and electrical conductivity of 1.22 dSm^{-1}

2.2. Genetic material and orchard management

Eleven olive cultivars were evaluated (Arbequina, Koroneiki, Arbosana, Kalamata, Barnea, Pendolino, Empeltre, Manzanilla de Sevilla, Carboncella, Frantoio and Cassaliva). Five trees per cultivar were used in this experiment. The trees were planted in the year 2011 at distance of 10 x 10 m, occupying an area of 5500 m^2. A drip irrigation method was used, arranged in simple rows with three drippers per tree and flow of 4.0 L h^{-1}. The annual volume

* E-mail address: xyz@abc.com.

of water applied was on average 7 200 m^3 ha^{-1}. A single pruning for conduction was carried out at planting, which consisted of eliminating secondary twigs of less 80 cm, leaving anything over this threshold to grow freely. Orchard olive was fertilized with 15-15-15 at rate of 1.5 kg per tree (234 kg ha^{-1}) during February and March and with ammonium nitrate (150 kg ha^{-1}) during the postharvest period. The olive harvest was done manually during first week October. Other agronomic practices were done in accordance to commercial recommendations (Grijalva et al., 2010).

2.3. Measurement variables

The parameter evaluated were: Trunk diameter (cm), canopy width (m), plant height (m), yield (kg $tree^{-1}$), olive quality (fruit weight, and pulp-pit ratio), finally the oil content which was determined using chemical analysis according to the methodology described by (AOAC, 1985), this parameter was evaluated only during 2016 year.

2.4. Statistical Analysis

This experiment was analyzed using a randomized complete block design and five replications. Means were compared by least difference test (LSD) at 5% level of significance. The analysis of variance and means tests were analyzed using the UANL computer package program (Olivares, 1994).

3. RESULTS AND DISCUSSION

3.1. Vegetative parameters

According to Table 1 there were statistical differences on all vegetative characteristics among cultivars. The trunk diameter showed difference at (P<0.05) the higher value was obtained in Pendolino cultivar with 14.3 cm although statistical equal to six cultivars, while Arbequina obtained the smallest diameter with 11.2 cm but without statistical difference to other four cultivars. By other side, the canopy width was affected statistically (P<0.01) among cultivars, being Manzanilla of Sevilla, Pendolino and Arbequina those higher values with 3.48, 3.46 and 3.26 m respectively, and lower value was for Arbosana with 2.64 although statistically equal to Empeltre and Frantoio cultivars. Finally plant height showed difference at (P<0.01) and the cultivar with higher value was for Empeltre with 3.92 m being statistically equal to Pendolino, Kalamata y Manzanilla de Sevilla cultivars. The lower plant height was obtained in Arbosana with 2.67 m but statistically equal to other seven cultivars. Empeltre cultivar obtained low canopy width (2.82 m) but greater height of plant (3.92 m) this due to the growth habit which is erect.

In general terms, the development and vegetative growth were different among cultivars, Arbosana, followed by Koronekii were the cultivars with low tree vigor for this reason, these cultivars together with Arbequina are recommended intensive production systems (Rius and Lacarte 2010; Lazicki and Geisseler 2016), although in this study Arbequina was significantly higher in canopy size and plant height, but lower trunk diameter. Similar results were found by (Reza et al., 2016; Sibbet et al., 2013) who found that Arbequina presented 25% less vigor than Arbosana and higher canopy area in comparison to other cultivars.

* E-mail address: xyz@abc.com.

Table 1. Vegetative characteristics of eleven olive cultivars at Experimental Station of Caborca, Sonora, Mexico.

Cultivar	Trunk diameter (cm)	Canopy width (m)	Plant height (m)
Arbequina	11.2 c	3.26 abc	3.27 bcd
Barnea	12.2 bc	3.10 cd	3.00 cd
Arbosana	13.4 ab	2.64 e	2.67 d
Carboncella	12.8 ab	3.18 bc	3.25 bcd
Koroneiki	12.4 ab	3.04 cd	2.92 cd
Manzanilla de Sevilla	12.7 bc	3.48 a	3.40 abc
Pendolino	14.3 a	3.46 ab	3.72 ab
Kalamata	12.7 bc	3.00 cd	3.65 ab
Empeltre	12.1 bc	2.82 de	3.92 a
Frantoio	13.4 ab	2.80 de	2.90 cd
Cassaliva	13.3 ab	3.12 c	2.95 cd
Significance	*	**	**
C.V. (%)	10.2	7.5	13.4

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

3.2. Olive yield and oil content

The results in Table 2 indicate that there was statistical difference ($P<0.01$) in olive yield in both years. The highest olive yield was obtained in Arbequina with 34.5 and 70.3 kg tree^{1} for 2015 and 2016 year respectively, obtaining an average yield of 52.4 kg tree^{1} for both years, being statistically different from the rest of the cultivars, followed by Barnea (34.45 kg tree^{-1}), Manzanilla de Sevilla (29.60 kg tree^{-1}), Carboncella (26.50 kg tree^{-1}), Arbosana (25.50 kg ha^{-1}) and Koroneiki (25.5 kg tree^{-1}). By other side Frantoio and Cassaliva were the lowest olive yield with 11.75 and 10.3 kg tree^{-1}, respectively. The high productivity of Arbequina and the differences in the yield among cultivars are in accordance by other researchers (Tous et al., 2002; Villamil et al., 2007; Tapia et al., 2009; Grijalva et al., 2014 and Reza et al., 2016). The differences found in this study among cultivars indicate a favorable situation for the selection of cultivars for hot and arid environment of Mexico and further indicate that the strategy of selecting cultivars is proving effective from the point of view of improving productivity.

The oil content showed statistical difference ($P<0.01$). Barnea variety was higher with 19.2%, followed by Kalamata with 15.2%, while that Pendolino variety recorded the lower oil content with only 9.1% (Figure 1). By other side, considering olive yield, oil content and plant density was obtained that Arbequina and Barnea were the varieties with the highest productivity, Arbequina yielded 462 kg ha^{-1} of oil in 2015 and 942 kg ha^{-1} in 2016 while que Barnea yielded 511 and 812 kg ha^{-1} for 2015 and 2016, respectively. Similar results were found by (Grijalva et al., 2014) but with Carolea variety. In general, the percentage of oil obtained among varieties evaluated was much lower than that found by most studies (Tous et al., 2002; Beltrán et al., 2003; Al-Maaitah et al., 2009; Tapia et al., 2009; Zeleke et al., 2012 and Reza et al., 2016). The oil content is determined mainly by varieties, harvest date (Al- Maaitah et al., 2009) and the difficulty in its extraction (Beltrán et al., 2003). The low percentage of oil found in this study may be to the high temperature (>40 °C) during the ripening process of the fruit.

* E-mail address: xyz@abc.com.

Table 2. Yield of eleven olive cultivars at Experimental Station of Caborca, Sonora, Mexico.

Cultivar	Yield (kg $tree^{-1}$)	
	2015	2016
Arbequina	34.5 a	70.3 a
Barnea	26.6 b	42.3 b
Manzanilla de Sevilla	19.0 bc	40.2 b
Carboncella	21.5 bc	31.5 bc
Arbosana	22.6 bc	28.4 bc
Koroneiki	20.5 bc	30.5 bc
Pendolino	18.5 c	28.9 bc
Kalamata	9.6 d	20.0 c
Empeltre	6.5 d	18.9 c
Frantoio	3.5 d	20.0 c
Cassaliva	3.2 d	17.4 c
Significance	**	**
C.V. (%)	33.1	28.7

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

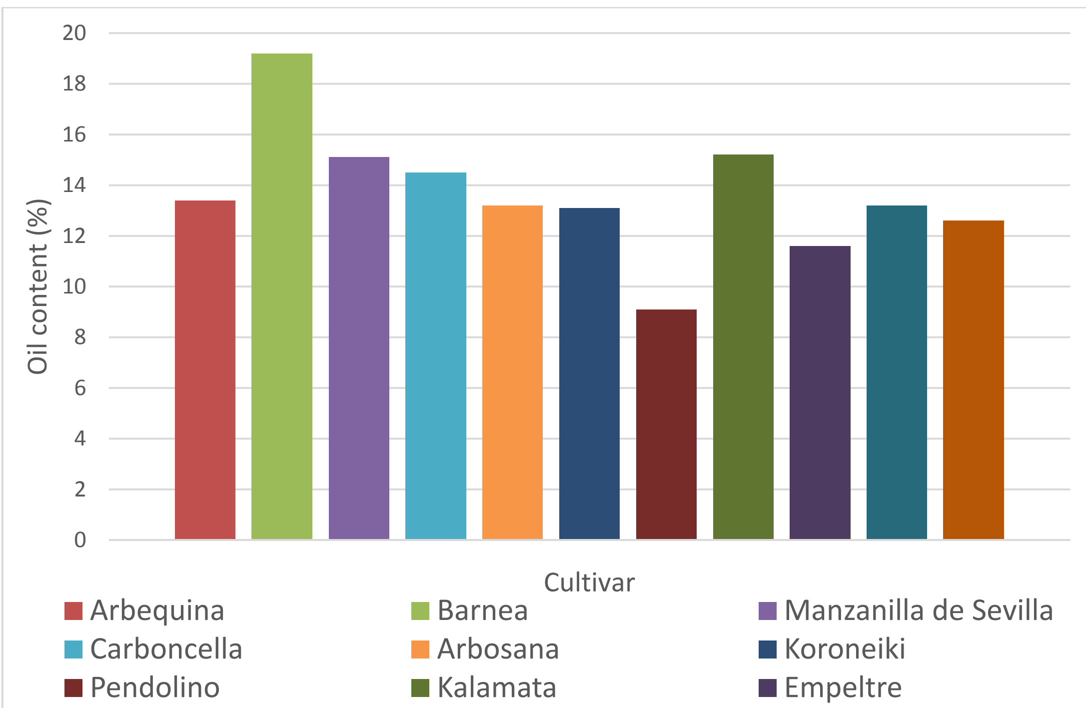

Figure 1. Oil content of eleven olive cultivars at Experimental Station of Caborca, Sonora, Mexico.

3.3. Fruit characteristics

In Table 3 are showed the fruit weight and pulp-pit ratio in both parameters there were statistical difference (P<0.01) The varieties with greater weight of fruit were Manzanilla de

* E-mail address: xyz@abc.com.

Sevilla and Barnea with 4.67 and 4.30 grams per fruit respectively and without statistical difference between both varieties, followed by Kalamata with 3.58 grams per fruit, while the varieties with the lowest fruit weight were Arbosana, Arbequina, Cassaliva and Koroneki with 1.33, 1.22, 1.21 and 0.96 grams per fruit, respectively.

Table 3. Fruit characteristics of eleven olive cultivars at Experimental Station Coast of Hermosillo, Sonora, Mexico.

Cultivar	Fruit weight (g)	Pulp-pit ratio
Arbequina	1.22 f	2.02 fg
Barnea	4.30 a	2.85 c
Arbosana	1.33 f	2.59 cd
Carboncella	2.79 c	3.16 b
Koroneiki	0.96 f	2.15 ef
Manzanilla de Sevilla	4.67 a	5.26 a
Pendolino	1.84 e	2.33 de
Kalamata	3.58 b	3.18 b
Empeltre	2.32 d	2.60 cd
Frantoio	2.04 de	1.72 g
Cassaliva	1.21 f	1.85 fg
Significance	**	**
C.V. (%)	5.2	6.7

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

The pulp-pit ratio was higher in Manzanilla de Sevilla with 5.26 and in second order Kalamata and Carboncella with 3.18 and 3.16 respectively and the lowest value was obtained in Frantoio with 1.72 although statistically equal to Cassaliva and Arbequina with 1.85 and 2.02, respectively. The values recorded about fruit characteristics among varieties are similar to those described by (Civantos, 2001; Reza et al., 2016). Olive size, pulp-pit ratio and pickling process facility are important characteristics for table olive production, while oil content and oil quality are important for oil production.

* E-mail address: xyz@abc.com.

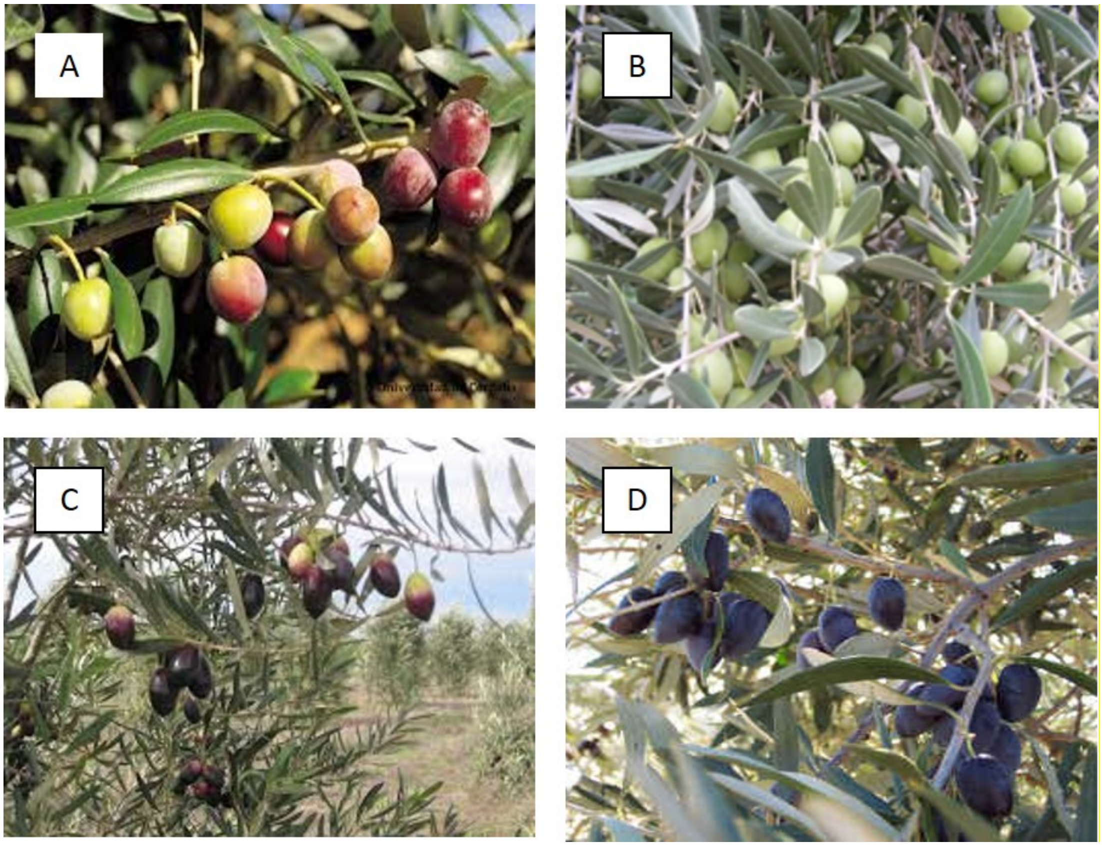

Figure 2. A). Arbequina cultivar, the most productive, but low oil content. B). Manzanilla of Sevilla, the main cultivar for table olive in Mexico and the world. C). Barnea cultivar, the higher oil content in Caborca, Sonora, Mexico. D). Kalamata cultivar, good alternative for table olive production for Mexico.

4. CONCLUSION

During two years of production, Arbosana obtained the lower vegetative development, Arbequina and Barnea recorded the higher olive yield and oil content, respectively.

Manzanilla of Sevilla and Barnea varieties, which are dedicated as table olives, represent a good option as double-purpose varieties.

Kalamata variety is good alternative as table olive although had low yield but is rewarded for its high price in the market.

ACKNOWLEDGEMENTS

This work was supported by the Fundation Produce Sonora A.C. and National Research Institute for Forestry, Agriculture and Livestock (Fiscal Project 13431434659) and 'SPR Campo Aguilar' for given all facilities conducting the field work.

* E-mail address: xyz@abc.com.

COMPETING INTEREST

Authors have declared that no competing interests exist.

REFERENCES

Association of Official Agricultural Chemist (AOAC). Official methods of analysis. 14th Edition. Benjamin Franklin Station. Washington D.C. 1985; p. 490-576.

Al-Maaitah, ML, Al-Absi KM, Ai-Rawashdeh A. Oil quality and quantity of three olive cultivars as influenced by harvesting date in the middle and Southern parts of Jordan. International Journal Agriculture Biology. 2009; 11:266-272.

Ávila-Escobedo MJ, Grijalva-Contreras RL,Guzmán-Maldonado SH, Villalobos-Reyes S. Mariscal-Amaro LA, Bujanos-Muñiz R, Cerón-Mendoza JF. Perspectivas y situación del olivo en Guanajuato. Folleto Técnico No.5. SAGARPA-INIFAP-CIRSE-CEBAJ. 2017; p 50. Spanish.

Beltrán G, Uceda M, Jiménez A, Aguilera, M.P. Olive oil extractability index as a parameter for olive cultivar characterization. Journal Science Food Agriculture. 2003; 83:503-506.

Benlloch M, Arboleda F, Barranco D, Fernández-Escobar R. Response of young olive trees to sodium and boron excess in irrigation water. HortScience.1991; 26:867-870.

Civantos L. Variedades y patrones. In Barranco D. Fernández-Escobar R, Rallo L. El cultivo del olivo. (Eds.). Cuarta Edición. Ediciones Mundi-Prensa. Madrid, España. 2001; pp-19-34. Spanish.

Consejo Oleico Internacional (COI). Cifras del mercado mundial del aceite de oliva. htpp:/wwwinternacionalolive.org. 2016; [Accessed April 2016].

Grijalva-Contreras RL, López-Carvajal A, Navarro-Ainza JAC, Fimbres-Fontes A. El cultivo del olivo bajo condiciones desérticas del Noroeste de Sonora. Folleto Técnico No. 41. SAGARPA-INIFAP-CECH-CECAB. 2010;100 p. Spanish.

Grijalva-Contreras RL, Macías-Duarte R, López-Carvajal A, Robles-Contreras F, Navarro-Ainza JC. Behavior of olive (*Olea europea* L) cultivars for oil under desert condition in Sonora. Revista Mexicana de Ciencias Agrícolas. 2014; 5:17-27. Spanish.

Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias INIFAP. Guía para la asistencia técnica agrícola. Área de influencia del Campo Experimental Región de Caborca, Sonora. México. 1985;10 p. Spanish.

Isidoro D, Aragúes R. Modeling survival of young olive trees (*Olea europea* L. cv. Arbequina) in saline and waterlogging field condition. Agronomy Journal. 2006;98: 795-799.

Lazicki P, Geisseler D. Olive production in California. California Department of food an Agriculture. Fertilizer Research and Education Program. 2016;3 p.

Olivares SA. Paquete de diseños experimentales FAUANL Versión 2.5 Facultad de Agronomía UANL. Marín N.L. México. 1994. Spanish.

* E-mail address: xyz@abc.com.

Perales-De la Cruz MA, Perales-Vega MA, Zacatenco GM. Hidrocálida primera variedad de olivo generada en México. In: Memorias de la 56 Reunión Anual del Programa Cooperativo Centroamericano para el Mejoramiento de Cultivos y Animales. El Salvador. 2011; pp 45-48. Spanish.

Reza MT, Asgar AZ, Asimoshtaghi E. Evaluating the performance of eleven olive cultivars in Fars Province of Iran. International Journal of Horticultural Science and Technology. 2016; 3:1-8.

Rius X, Lacarte JM. La revolución del olivar. El cultivo en seto. Barcelona, España. 2010; pp 67-90. Spanish.

Ruiz CJ, Medina GG, Grageda GJ, Silva SMM, Díaz PG. Estadísticas climatológicas básicas del Estado de Sonora (Periodo 1961-2003). INIFAP-CIRNO-SAGARPA. Libro Técnico No. 1. México. 2005; pp 92-93. Spanish.

Servicio de Información Agroalimentaria y Pesquera (SIAP). Secretara de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación (SAGARPA). htpp:/www.siap.gob.mx. 2014; [Accessed June 2014]. Spanish.

Sibbet GS, Ferguson L, Fichtner E. Best practices for olive grower. htpp://olivecenter.ucdavis.edu/learn/grower. 2013; [Accessed, May 2018].

Tapia CF. Mora F, Santos IA. Preliminary evaluation of 29 olives (*Olea europea* L.) cultivars for production and alternate bearing in the Huasco Valley Northern Chile. Chilean Journal of Agricultural Research. 2009; 69:325-330.

Tous J, Romero A, Hermoso JF. Behavior of ten mediterranean olive cultivars in the Northeast of Spain. Acta Horticulturae. 2002; 586:113-116.

Villamil J, Cabrera D, Villamil JJ, Rodríguez P. Evaluación de variedades de olivo. Serie de actividades de difusión No.512. Instituto Nacional de Investigación Agropecuaria. Uruguay. 2007.6 p.

Zeleke K, Mailer R, Eberbach P, Wünche R. Oil content and fruit quality of nine olives (*Olea europaea* L) varieties affected by irrigation and harvest time. New Zealand Journal of Crop and Horticultural Science. 2012;40: 241-252.

* E-mail address: xyz@abc.com.