Int.J.Curr.Microbiol.App.Sci (2017) *6*(8): 2120-2130

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 6 Number 8 (2017) pp. 2120-2130**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2017.608.252

Genetic Divergence of Horticultural Traits among Olive (*Olea europea* L.) Genotypes Grown in Temperate Climate

S. Lal*, O.C. Sharma, D.B. Singh, S.A. Rather, Bilal A. Padder and I. Qureshi

ICAR- Central Institute of Temperate Horticulture
K.D. Farm, Old Air Field, Rangreth, Srinagar-190 007 (J&K), India
**Corresponding author*

Keywords

Olive, Genetic divergence, Horticultural traits, Temperate.

Article Info

Accepted:
19 June 2017
Available Online:
10 August 2017

A B S T R A C T

The present investigation for assessment of genetic divergence of horticultural traits in 18 olive genotypes was carried out at experimental farm of ICAR-CITH, Srinagar. All the selected genotypes differed significantly for selected traits. Thirteen economic traits were scored and subjected to multivariate analysis. Results revealed a considerable phenotypic variability among olive genotypes. The cluster analysis classified genotypes into two major groups according to their potential characteristics. The first group was found superior in terms of narrowest leaf, longest fruit size, high fruit firmness, high pulp content, high fruit shape index and low yield per plant and second cluster in longest leaf, thickest leaf, high fruit weight, low firmness and high yield per plant attributes. Principal component analysis (PCA) revealed that The first PC, which is the most important component, explained 29.05% of total variation and was positively related to leaf length and leaf length/width ratio, leaf thickness, oil content (fresh and dry weight basis), stone weight, yield per plant. Among genotypes most diverse genotypes were Picholine, Cipressino, Toffohai, Coratina and Cornicobra which could be utilized as donor parents to begin crossing in European olive as well as in Indian olive species and breeding programs which may result in increase in the desired traits such as fruit size, oil content and yield.

Introduction

Olive (*Olea europaea* L.) is undoubtedly one of the world's oldest cultivated crop originated from Asia Minor and has tremendous potential in India especially in mid hills and warm temperate regions of North Western Himalaya (Lal *et al.*, 2017). It is of great economic importance throughout the world especially in Mediterranean countries because of the oil extracted from its fruits (Orlandi *et al.*, 2004). Majority of olive producing countries lie in the Mediterranean basin and contribute around 98% of the world's total production of olive and olive products. It is grown over an area of about 9.4 million hectares in the world with a production of 20.81 m tonnes and a productivity of 2.10 t/ha (FAO, 2014). Spain is a leader with production of 4.56 m tonnes from an area of 2.52 million hectares however, highest productivity of 9.29 t/ha has been recorded from Egypt (FAO, 2014). In Asia, cultivation is mostly confined to Iraq, Iran and China, however, in India in-spite of its vast potential it is only grown in the

Himalayan mountainous region encompassing the three northern states viz. Jammu and Kashmir, Himachal Pradesh and Uttarakhand at an altitude ranging from 1000 to 1300 m above mean sea level and also to small scale in Rajasthan. Among the states, Jammu and Kashmir leads in European olive cultivation having a total of 707 ha area spread in the districts of Doda, Ramban, Udhampur, Rajouri, Poonch, Kupwara, and Baramulla (DOH, 2015). Besides *Olea ferruginea* Royle (syn. *O. cuspidata* Wall. Ex G. Don), generally known as Indian olive, is one of the six species of *Olea* found in India, widely been grown in the Himalayas from Kashmir to Kumaun up to an altitude of 2400 m (Anon, 1997; Bartolucci *et al.,* 1999). Olive is mostly grown for extraction of oil and is also utilized for table purposes and pickles. In India, the demand of olive is increasing rapidly due to its peculiar medicinal and antioxidental properties (IOOC, 2011) but indigenous olive species has low fruit yield and oil content (Joshi, 2011). Olive oil is commonly used for cooking and industrial purposes for cosmetics, pharmaceuticals, soaps and as fuel for traditional oil lamps. It has a high content of monounsaturated fat (mainly oleic acid) and polyphenols which are beneficial for health. It is a rich source of polyunsaturated fatty acid (PUFA) and is absolutely free from cholesterol (Verma *et al.*, 2010).

In last few years there has been a tremendous growth in import quantity. During the year 2000, the total olive import was 523 tonns only which increased to 11965 tonns during 2013 (FAO, 2014) clearly showing a great potential of this oil crop in India. Increasing the area of olive cultivation in mid warm temperate and temperate regions will not only augment to our oil requirement but can also save foreign exchange. Initial performance studies of exotic olive genotypes under temperate and sub-temperate regions showed positive results for fruit and oil yield (Singh *et al.,* 1986; CITH, 2013) but still there is a great scope to enhance productivity of fruit and oil yield. There is also a need of superior donor parents for improvement of Indian olive species with respect to oil, fruit size and fruit yield. Identification and description of the genetic variability of available and existing germplasm of any crop is a preliminary requirement for the exploitation of useful traits in fruit crop improvement (Khush, 2002). The aim of the present investigation was to determine the genetic variability among exotic olive genotypes for leaf, fruit, oil, yield and yield attributing traits for identification of superior and diverse parents for formulating breeding and germplasm management strategies as well as improvement of indigenous olive species.

Materials and Methods

The current investigation was conducted at ICAR-Central Institute of Temperate Horticulture, Srinagar, J&K, India. The Research farm at Srinagar is situated at a latitude of 34° 05'N and longitude of 74° 50'E and at an altitude of 1640 m above mean sea level. Recommended package of practices were followed for healthy crop. The average maximum temperature 20.13°C, minimum 7.52 °C, rainfall 820 mm, relative humidity 60.45% and evaporation 2.85/day and soil characteristics, viz. pH= 6.81, EC = 0.36 dS/m were recorded in during the study period. This study was conducted during the year 2012- 2016 on 18 diverse olive genotypes conserved at olive germplasm block of ICAR-CITH, Srinagar (Table 1). The olive genotypes were sourced from UC-DAVIS, California and Egypt *via* NBPGR, New Delhi. The trees were planted at a spacing of 5.0 m × 5.0 m. The observation on leaf, fruit, oil and yield were recorded in the laboratory as per standard methods. A total of 10 mature leaf sample and fully ripened

twenty five fruits from each genotype were randomly collected during November for recording observations. The length and diameter of leaf and fruits were measured by digital Vernier caliper. Leaf and fruit shape was determined by calculating the ratio of leaf length and leaf width & fruit length and diameter, respectively whereas; fruit weight was measured using Sartorius balance with accuracy of 0.001 g. The stones were manually separated from the ripe fruits and pulp and stone characteristics were also measured. The yield per plant has been recorded over the study period by counting number of fruits and multiplying with average fruit weight. Fruit firmness was recorded by digital firmness meter and oil content was estimated using standard soxhlet method. The experiment was conducted under randomized block design with three replications and pooled data of six years were analyzed as per the method suggested by Gomez and Gomez (1984). Biometrical descriptive analysis was performed as grouping or classification of genotypes based on suitable scale is quite imperative to understand the usable variability existing among them. To explore the diversity and relationship among 18 genotypes, their vital morphological characteristics were studied by the multivariate factor analysis. To find out significance level, ANOVA performed using PROC GLM, clustering of genotypes into similarity groups was performed using the method tree procedure PROC CLUSTER based on average distance. In order to identify the patterns of variation in leaf, fruit, oil and yield, principal component analysis (PCA) was conducted as PROC PRINCOP in the SAS 9.3 software (SAS Institute, 2013 Cary, NC).

Results and Discussion

The analyzed data pertaining to 13 horticultural traits of 18 olive genotypes are given in table 2. The results showed significant differences among the genotypes during the study period for all the characters studied (Table 2). Among leaf characteristics the longest leaf was measured in Messenese which was *at par* with Ottobratica, Cerignola and Leccino, however, shortest leaf in Picholine which was *at par* with Itrana. The widest leaf was observed in Toffohai followed by Cippressino, Ottobratica and Cornicobra, however, narrowest leaf in Etnea followed by Frontoio and Pendolino. The leaf shape index was highest in Leccino followed by Etnea and Cerignola whereas, lowest in Toffohai followed by Cornicobra and Cipressino. The thickest leaf was measured in Coratina followed by Etnea, Cipressino and Picholine, however, thinnest leaf in Messenese. Since leaf characteristics are sign of drought tolerance and high photosynthetic efficiency. The leaf thickness increases as drought occurs and protects the water losses from plants. A thicker palisade parenchyma could contain larger numbers of CO_2-fixation sites, while a thicker spongy parenchyma could result in easier diffusion of CO_2 to these sites (Ennajeh *et al.,* 2010). These genotypic differentials in leaf morphology and anatomy can explain, at least in part, the difference in drought resistance between the two cultivars. It could be considered key structural features of leaves that govern the ability of a tree to withstand water stress. They could therefore be used as criteria to select olive cultivars that are more resistant to drought with high photosynthetic efficiency (Leon *et al.,* 2005; Ennajeh *et al.,* 2010).

Among fruit characteristics, longest fruit was observed in genotype Cornicobra while shortest was in Belice. Likewise the maximum fruit diameter was recorded in genotype Picholine and lowest in Cipressino which was statistically found *at par* with Etnea and Itrana. Fruit shape index was measured highest in genotype Cornicobra which was *at par* with Cipressino and

Messenese, however, lowest in Cerignola. The heaviest fruit was noted in Coratina which was *at par* with Toffohai and Tonda Ibea and lightest in Pendolino. Maximum oil content on fresh and dry weight basis was estimated in genotype Cipressino, however, minimum in terms of fresh weight was recorded in Morolio and on dry weight basis in Ottobratica, respectively. Firmest fruit was observed in Toffahai and lowest firm fruit was in Cerignola. Highest pulp weight was estimated in genotype Toffohai which was *at par* with Coratina, however, lowest in Pendolino. Among stone characteristics maximum stone weight was observed in genotype Picholine and lowest in Ottobratica whereas highest stone length was measured in genotype Toffahai and lowest in Cipressino. Similarly highest stone diameter was noticed in genotype Picholine and lowest in Cipressino. Among all the genotypes highest yield per plant was noted in genotype Cipressino and Picholine and lowest in Morolio. Similar kind of variability was also reported in yield and yield attributes by Fontanzza *et al.,* (1999), Hosseini *et al.,* (2008), Sheidaia *et al*., (2010) and Dastkar *et al.,* (2013) in olive.

Descriptive statistics was given in table 3 and its revealed the maximum standard deviation was observed for oil content (DW) followed by yield per plant, oil content (FW) and leaf thickness and minimum in fruit shape index followed by stone weight. Likewise maximum coefficient of variation in yield per plant followed by leaf width, and leaf length/width ratio, however minimum in leaf thickness, stone length and fruit length, the results are in line with Cantini *et al.,* (1999), Rio *et al.,* (2008), Jalali *et al.,* (2014) and Mardi *et al.,* (2016) who also reported similar genetic variability in olive genotypes in their respective studies. Skewness describes the symmetrical distribution pattern with respect to its dispersion from the mean. The skewness values showed that the data for most of the traits were normally skewed which was less than ±2 except for leaf width. Positive skewness was recorded for leaf length, leaf width, fruit diameter, firmness index, stone weight and yield per plant, however, negative skewness was recorded for leaf length/width ratio, leaf thickness followed by fruit length, fruit shape index, fruit weight, oil content, pulp weight, stone weight, stone length and stone diameter. Kurtosis tells the weight of the tails of a distribution. These results showed the distribution of quantitative traits which provides information about nature of gene action and number of genes controlling the traits respectively. The skewed distribution of a trait in general suggests that the trait is under the control of non-additive gene action and is influenced by environmental variables.

Positive skewness is associated with complementary gene interactions while negative skewness is associated with duplicate (additive × additive) gene interactions. The genes controlling the trait with skewed distribution tend to be predominantly dominant irrespective of whether they have increasing or decreasing effect on the trait. In the present set of data it was recorded platykurtic distribution pattern for leaf width, leaf length/width ratio, leaf thickness, stone weight, stone length, stone diameter and yield per plant, however, leptokurtic distribution for leaf length, fruit length, fruit diameter, fruit shape index, fruit weight, oil content, firmness index and pulp weight. Kurtosis is negative or close to zero in the absence of gene interaction and is positive in the presence of gene interactions. The traits with leptokurtic and platykurtic distribution are controlled by fewer and large number of genes, respectively. Bimodality of genetic admixture values provides evidence of strong isolation between two morphological and genetic clusters, supporting the existence of a

sympatric genotypes pair within the gene pool. In the present study, values are near to zero, explains the closeness among the genotypes for the traits under study.

The dendrogram generated from the linkage cluster analysis based on average distance, classified 18 olive genotypes into two major groups (Fig. 1) at normalized root mean square (NRMS) distance 1.41. The first group consisted of only two genotypes that contributed 11.11% of the total genotypes in this population, and further this group categorised in to two clusters and in each cluster only one genotype existed. The first cluster consisted of genotype Cipressino which was characterized by lowest fruit diameter and highest yield per plant, however, second cluster consisting of Picholine was characterized by maximum fruit diameter, high oil content, highest stone weight and high yield per plant. The second group consisted of 16 genotypes and contributed 88.88% of the total genotypes in this population which was further broadly categorized in two broad clusters at 1.02 NRMS. The first cluster includes eight genotypes (Ottobratica, Tonda Ibea, Biancolillo, Belice, Morolio, Cornicobra morolio, Etnea and Toffohai) and it had the narrowest leaf, longest fruit size, high fruit firmness, high pulp content, high fruit shape index and low yield per plant. Similarly the second cluster also consisted of eight genotypes namely Messenese, Cipressino, Zaituna, Frontoio, Itrana, Coratina, Pendolino, Leccino and Cerignola. It was characterized by longest leaf, thickest leaf, high fruit weight, low firmness and high yield per plant. The dissimilarity level in terms of genetic distance ranged from 0.317-1.41 indicating a high degree of dissimilarity between genotypes and high genetic distance between genotypes and if chosen for hybridization program, may give high heterotic F1s and broad spectrum of variability in segregating generations. Principal components analysis is a way of identifying patterns in data, which expresses data in such a way as to highlight their similarities and differences (Verma *et al.*, 2014; Lal *et al.*, 2013). Therefore, it was carried out to determine the characters more strongly contributed to the principal components. Principal components analysis reduced the original 13 characters in experiment to five principal components (Table 4). The first five principal components with Eigen values >1 explained 80.00% of variation among 18 genotypes (Table 3). Other PCs had Eigen values ≤1 and excluded in interpretation. The first PC, which is the most important component, explained 29.05% of total variation and was positively related to leaf length and leaf length/width ratio, leaf thickness, oil content (fresh and dry weight basis), stone weight, yield per plant. The PC2 accounted for 19.07% of the total variation and the characters with the greatest weight on this component were fruit diameter, firmness index, stone length and stone diameter. The PC3 accounted for 15.00% and positively related to leaf width, leaf length, fruit length and fruit shape index, however PC4 accounted for leaf length and pulp weight. The PC5 accounted for fruit length suggesting that these principal component score might be used to summarize the 13 variables in any further analysis of data. The traits with largest absolute value closer to unity within the first component influence the clustering than those to lower absolute value closer to zero. Thus, in present study differentiation of genotypes into different components was because of high contribution of few traits rather than small contribution of each trait. The positive and negative loadings show positive and negative correlation trends between the component and variable. Thus, above mentioned characters which load high positively or negatively contributed to more diversity. This situation confirms the suitability of using horticultural traits as a

basis for selecting parental sources; nevertheless, studies for several years must be conducted before parental selection for a possible plant breeding. The PC analysis provided a simplified classification of the olive genotypes for conservation and breeding.

The biplot axes also showed geometrical distances among the genotypes that reflect similarity among them in terms of variables measured (Fig. 2). The first two principal component scores were plotted to aid visualization of accessions grouping. The derived cluster and subgroups were very similar to those identified from average distance between the cluster analyses. More interesting genotypes were Picholine, Cipressino, Toffohai, Cornicobra and Coratina those were disposed in gaps and are the most promising ones. Genotype Picholine was characterized by the highest fruit diameter, stone weight, stone diameter and highest yield and Cipressino was characterized for the highest oil content on fresh and dry weight basis and yield per plant. Genotype Toffohai was characterized by the highest fruit firmness and pulp weight. However, Cornicobra had the longest fruits & fruit shape index, Coratina had thickest leaf, fruit weight and pulp weight. So, it can be intended for further utilization for introducing these traits in desired genotypes or in improvement of Indian olive. The results of study are useful as it furnish the information about the groups, where certain traits are more important allowing the breeder to execute the specific breeding programme with higher yield and better flesh core ratios. The biological implication of principal component analysis can be quantified from the contribution of different variables to each principal component as revealed by Eigen vector.

Table.1 List of genotypes used in study

S. N.	Genotype	Source	S. No.	Genotype	Source
1	Ottobratica	NBPGR, New Delhi	10	Pendelino	NBPGR, New Delhi
2	Morolio	NBPGR, New Delhi	11	Messenese	NBPGR, New Delhi
3	Cornicobra	NBPGR, New Delhi	12	Cipressino	NBPGR, New Delhi
4	Toffohai	NBPGR, New Delhi	13	Leccino	NBPGR, New Delhi
5	Tonda Ibea	NBPGR, New Delhi	14	Picholine	NBPGR, New Delhi
6	Biancolillo	NBPGR, New Delhi	15	Itrana	NBPGR, New Delhi
7	Etnea	NBPGR, New Delhi	16	Frontoio	NBPGR, New Delhi
8	Cerignola	NBPGR, New Delhi	17	Coratina	NBPGR, New Delhi
9	Zaituna	NBPGR, New Delhi	18	Belice	NBPGR, New Delhi

Table.2 Leaf, fruit, oil and yield attributes of olive genotypes evaluated in North West Himalayan region of India

S. No.	Genotype	Leaf length (cm)	Leaf width (cm)	L/W	Leaf thickness (mm)	Fruit Length (mm)	Fruit Diameter (mm)	FSI	Fruit Weight (g)	Oil Content FW (%)	Oil Content DW (%)	Firmness index	Pulp Weight (g)	Stone Weight (g)	Stone Length (mm)	Stone Diameter (mm)	Yield (kg)/plant
1	Ottobratica	6.32	2.13	2.97	57.08	20.48	14.88	1.38	3.28	15.30	23.00	9.21	2.77	0.52	14.81	8.14	2.99
2	Morolio	5.32	1.66	3.20	53.34	22.23	16.19	1.37	3.51	14.40	25.00	8.22	2.83	0.68	15.35	7.77	0.40
3	Cornicobra	5.29	2.08	2.54	54.73	23.10	14.64	1.58	3.51	17.24	29.00	8.92	2.89	0.62	14.92	8.13	2.65
4	Toffohai	6.24	6.16	1.01	52.35	20.54	14.64	1.40	3.77	19.89	30.00	9.80	3.21	0.55	16.90	8.46	5.10
5	Tonda Ibea	5.3	1.69	3.14	54.37	20.56	14.23	1.44	3.77	16.20	24.00	8.32	3.08	0.69	15.76	7.99	6.40
6	Biancolillo	5.51	1.59	3.47	56.67	20.69	14.07	1.48	2.62	15.65	26.00	7.88	1.96	0.66	15.02	8.02	5.33
7	Etnea	5.93	1.24	4.78	57.56	19.58	13.32	1.47	3.59	18.96	31.00	7.99	2.92	0.68	13.80	7.74	3.70
8	Cerignola	6.4	1.38	4.64	55.67	18.67	15.81	1.18	3.01	22.36	33.00	7.54	2.36	0.65	15.54	7.93	8.05
9	Zaituna	5.29	1.85	2.86	56.33	22.22	16.14	1.38	3.54	20.31	31.00	9.56	2.98	0.55	15.43	9.05	11.50
10	Pendelino	5.58	1.28	4.36	56.67	21.21	14.26	1.49	2.17	21.35	35.00	7.78	1.35	0.82	16.13	8.16	9.39
11	Messenese	6.84	1.51	4.53	49.89	21.66	14.08	1.54	3.06	22.68	39.00	8.45	2.22	0.84	15.18	7.34	7.25
12	Cipressino	6.19	2.21	2.80	57.33	20.49	13.26	1.55	2.30	23.34	41.00	8.76	1.39	0.92	13.05	6.38	16.90
13	Leccino	6.4	1.33	4.81	54.44	20.73	16.13	1.28	2.40	22.50	32.99	8.98	1.49	0.91	15.25	9.21	5.66
14	Picholine	4.53	1.5	3.02	57.33	20.88	16.76	1.24	2.50	21.78	38.00	9.11	1.46	1.05	16.18	9.33	16.87
15	Itrana	4.64	1.35	3.44	55.11	18.55	13.32	1.39	3.18	17.42	36.00	8.34	2.47	0.71	14.95	8.16	5.68
16	Frontoio	5.48	1.27	4.31	56	18.89	15.66	1.21	2.61	20.65	37.00	8.23	2.02	0.59	15.08	7.99	7.07
17	Coratina	5.37	1.86	2.89	58.89	21.71	15.32	1.41	3.85	19.89	34.00	8.56	3.13	0.72	15.77	7.96	7.84
18	Belice	5.03	1.36	3.70	53.3	17.93	14.12	1.27	2.89	16.54	26	8.29	2.2	0.69	13.77	7.77	3.24
LSD ≤0.05	--	2.05	0.94	1.59	5.67	3.16	1.86	0.22	1.02	1.00	1.63	0.54	1.09	0.29	1.91	0.79	3.23

Table.3 Descriptive statistics for thirteen horticultural and oil traits of 18 olive genotypes

Variable	Range	Mean	Standard Deviation	CV	Skewness	Kurtosis	Bimodality
Leaf length (cm)	4.53-6.84	5.65	0.64	11.35	0.10	-0.69	0.35
Leaf width (cm)	1.24-2.21	1.86	1.12	60.12	3.72	14.85	0.80
L/W	2.54-4.81	3.47	0.98	28.18	-0.56	0.81	0.30
Leaf thickness (mm)	49.89-58.89	55.39	2.20	3.98	-0.85	0.86	0.39
Fruit Length (mm)	17.93-23.10	20.56	1.40	6.82	-0.24	-0.44	0.33
Fruit Diameter (mm)	13.26-16.76	14.82	1.09	7.37	0.19	-1.13	0.42
FSI	1.18-1.58	1.39	0.12	8.49	-0.26	-0.79	0.38
Fruit Weight (g)	2.17-3.85	3.09	0.55	17.82	-0.21	-1.34	0.46
Oil Content FW (%)	14.40-23.34	19.25	2.87	14.89	-0.23	-1.35	0.46
Oil Content DW (%)	23.00-41.00	31.72	5.43	17.12	-0.05	-1.05	0.39
Firmness index	7.54-9.80	8.55	0.62	7.21	0.42	-0.40	0.36
Pulp Weight (g)	1.35-3.21	2.37	0.64	27.15	-0.38	-1.27	0.49
Stone Weight (g)	0.52-1.05	0.71	0.14	20.02	0.87	0.33	0.44
Stone Length (mm)	13.05-16.9	15.16	0.92	6.09	-0.58	0.82	0.30
Stone Diameter (mm)	6.38-9.33	8.09	0.68	8.35	-0.25	1.91	0.19
Yield (kg)/plant	0.40-16.90	7.00	4.45	63.61	1.12	1.16	0.47

Table.4 Principal component analysis of the olive genotypes showing the Eigen vectors, Eigen values and percentage total variance accounted for by the thirteen principal component axes

Characters	PRIN1	PRIN2	PRIN3	PRIN4	PRIN5
Leaf length (cm)	0.035	-0.079	0.287	0.576	0.095
Leaf width (cm)	-0.253	0.222	0.323	0.194	-0.338
L/W	0.287	-0.235	-0.261	0.260	0.272
Leaf thickness (mm)	0.111	0.035	-0.121	-0.533	-0.192
Fruit Length (mm)	-0.131	0.216	0.242	-0.195	0.661
Fruit Diameter (mm)	-0.003	0.408	-0.327	0.105	0.188
FSI	-0.081	-0.182	0.485	-0.247	0.364
Fruit Weight (g)	-0.395	-0.017	0.032	-0.017	0.002
Oil Content FW (%)	0.322	0.232	0.222	0.251	-0.071
Oil Content DW (%)	0.345	0.147	0.239	0.037	-0.104
Firmness index	-0.174	0.382	0.229	-0.037	-0.151
Pulp Weight (g)	-0.414	-0.047	0.004	0.008	-0.044
Stone Weight (g)	0.354	0.137	0.104	-0.111	0.206
Stone Length (mm)	-0.133	0.395	-0.107	0.172	0.171
Stone Diameter (mm)	-0.063	0.409	-0.332	0.002	0.107
Yield (kg)/plant	0.299	0.275	0.194	-0.245	-0.192
Eigenvalue	4.65	3.05	2.39	1.55	1.21
Difference	1.60	0.66	0.84	0.34	0.31
Proportion	0.29	0.19	0.15	0.10	0.08
Cumulative	0.29	0.48	0.63	0.73	0.80

Fig.1 Dendrogram of 18 olive (*Olea europea* L.) genotypes obtained by average distance between clusters based on 13 leaf, fruit quality, oil and yield traits

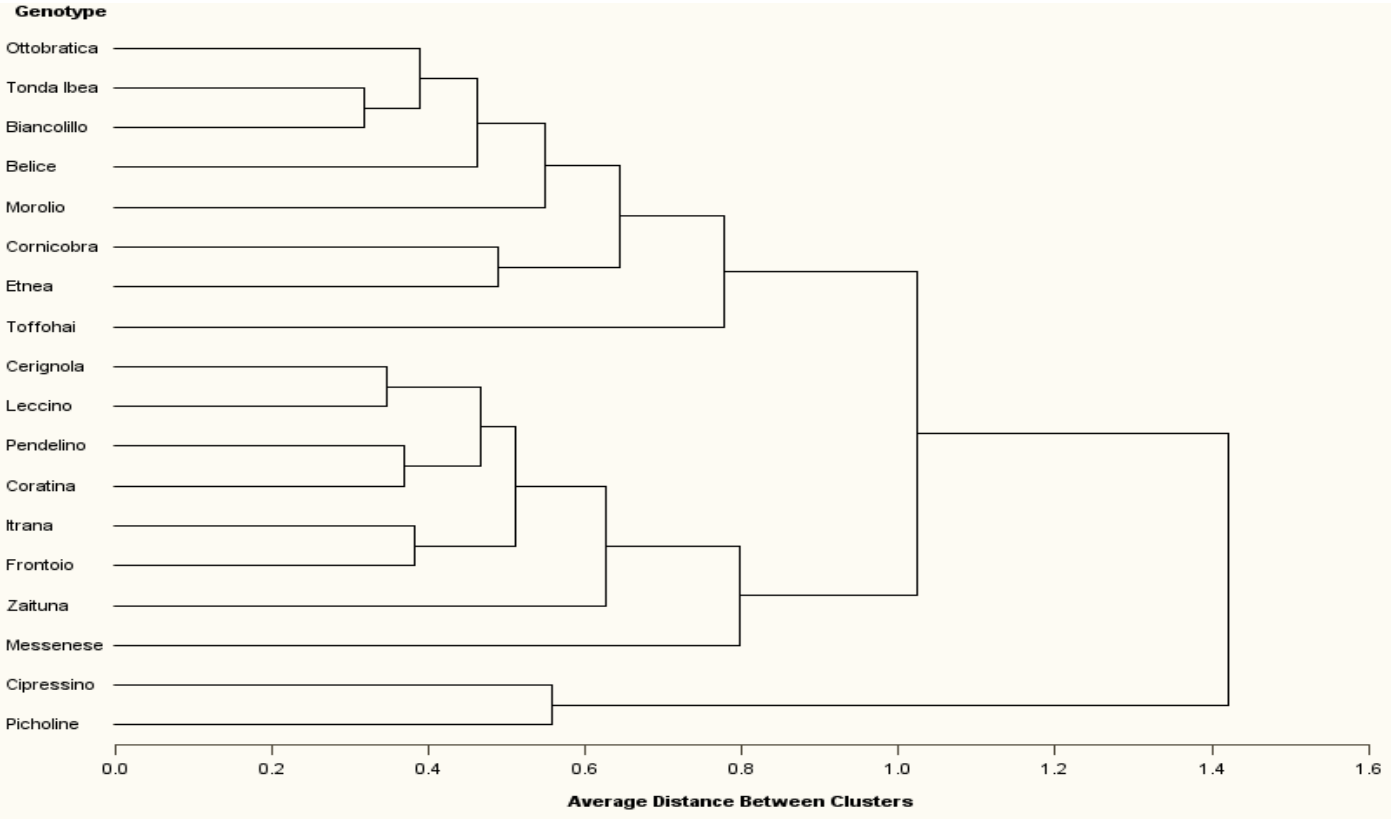
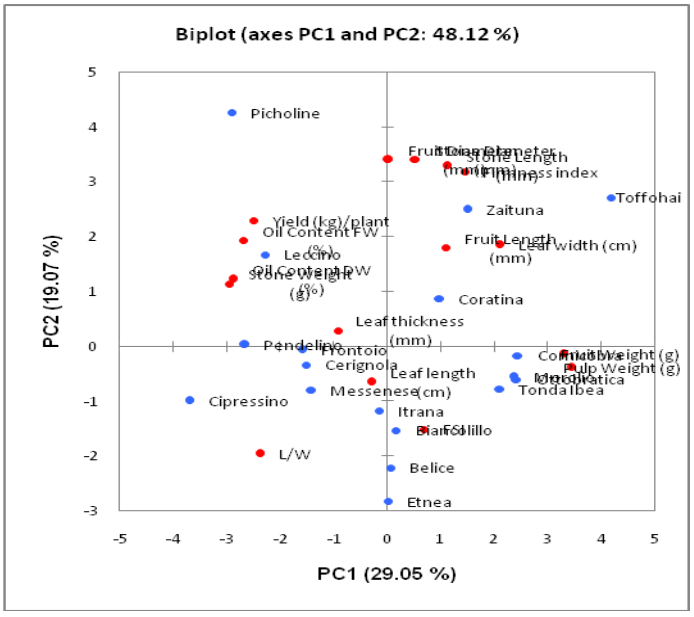


Fig.2 Segregation of 18 olive genotypes according to their leaf, fruit, oil and yield characteristics determined by principal component analysis. Vectors represent the loading of leaf, fruit, oil and yield traits data along with the principal component scores



The clustering score among the principal component axes suggest that some relationship exists among the individuals within a cluster but it does not provide a clear position of genotypes in that case, cluster analysis distance is a better approach. This cluster analysis classified all the genotypes into two major groups and further in clusters according to their potential characteristics. The first group genotypes were superior in terms of fruit diameter, stone weight, high oil content, low stone weight and yield per plant traits and second group genotypes in fruit weight, fruit firmness, fruit shape index, fruit length and stone attributes. Among genotypes most diverse genotypes were Picholine, Cipressino, Toffohai, Coratina, Cornicobra and Coratina which could be utilized as donor parents to begin crossing in European olive as well as in Indian olive species and breeding programs which may result in increase in the desired traits such as fruit size, oil content and yield. However, morphological descriptors which are environmentally influenced are not enough to identify the genotypes because of differences among them are ambiguous hence; molecular markers are required to validate the study.

References

Anon. 1997. The Wealth of India, Vol. VII. CSIR, New Delhi, India.

Bartolucci, P. and Dhakal, B.R. 1999. Prospects for Olive Growing in Nepal, His Majesty's Gov., Dep. Agric., Fruit Dev. Div., Olive Prod. Dev. & FAO, Kathmandu, Nepal.

Cantini, C., Cimato, A. and Sani, G. 1999. Morphological evaluation of olive germplasm present in Tuscany region. *Euphytica*, 109(3): 173-181.

Central Institute of Temperate Horticulture, Srinagar, J&K, 14p.

CITH. 2013. ICAR-Central Institute of Temperate Horticulture annual report, 2 012-13, P21.

Dastkara, E., Soleimanib, A., Jafaryc, H. and Naghavid, M.R. 2013. Genetic and morphological variation in Iranian olive (*Olea europaea* L.) germplasm. *Crop Breed J.*, 3(2): 99-106.

DOH. 2015. Directorate of Horticulture Kashmir.*http://hortikashmir.gov.in/AREA%20PROD%20NET/AP-2005-06.pdf*

FAO. 2014. Food and Agriculture organization statistics. http://www.fao.org/faostat/en/#data/QC.

Fontanzza, G., Vergari, G.P., Giorio, G. 1999. Preliminary results of the evaluation of yield component in an F1 segregent populations of olive seedlings from the cross Leccinox Kalamata. *Acta Hort.*, ISHS), 474: 97-101.

Gomez, K.A. and Gomez, A.A. 1984. Statistical Procedures for Agricultural Research, 2nd John Wiley and Sons Inc., New York.

Hosseini, M.M., Samaee, S.M., Ataei, S., Sadeghi, A. and Mirmansoori, A. 2008. Multivariate analysis of intra-cultivar variation of a local olive cultivar in the northern part of Iran using morphological traits. *Acta Hort.*, ISHS, 791: 65-71.

IOOC. 2011. http://www.oliveoiltimes.com/olive-oil-usiness/asia/vn-dalmia/22055.

Jalali, A., Seifi, E., Alizade, M. and Fereidooni, H. 2014. The study of morphological diversity among some olive genotypes in Northern Iran. *Asian J. Microbiol. Biotechnol. Environ. Sci.*, 16(4): 1007-1013.

Joshi, S. 2011. *Olea ferruginea* Royle, Indian olive: an under utilised fruit tree crop of North-west Himalaya. *Fruits*, 67(2): 121-126.

Khush, G.S. 2002. Molecular genetics-plant breeder's perspective. In: S.M. Jain,

D.S. Brar, and B.S. Ahloowalia (eds.. Molecular techniques in crop improvement, Kluwer Academic Publishers, Dordrecht, The Netherlands, p. 1-8.

Lal, S., Ahmed, N., Singh, S.R., Singh, D.B., Sharma, O.C., Kumar, R. 2013. Variability for health and bioactive compounds in strawberry (*Fragaria x ananassa* Duch.) cultivars grown under Indian temperate ecosystem. *Fruits*, 68(5): 423-434.

Lal, S., Singh, D.B., Sharma, O.C., Mir, J.I., Sharma, A. and Padder, B.A. 2017. Olive cultivation. *Tech. Bull.*, 1/2017. ICAR-Central Institute of Temperate Horticulture, Srinagar, 14p.

Leon, L., Del, R.R., Barranco, D. and Rallo, L. 2005. Selection for fruit removal force and related characteristics in olive breeding progenies. *Aust. J. Exp. Agric.*, 45: 1643-1647.

Mardi, M., Zeinalabedini, M., Mousavi-Derazmahalleh, S.M., Zeinanloo, A.A., Majidian, P., Kolahi-Zonoozi, S.H., Taslimpor, M.R., Masoomi-Majareh, S.A., Jamgard, F.A. and Mostafavi, K. 2016. Commercial Iranian olive cultivars: morphological traits, molecular diversity, and genetic structure. *J. Horticultural Sci. Biotechnol.*, 91(4): 404-411.

Orlandi, F., Garcia-Mozo, F., Vazquez, E.L., Romano, B., Dominguez, E., Galan, C. and Fornaciari, M. 2004. Phenological olive chilling requirements in Unbria (Italy) and Andalusia (Spain). *Pl Biosys.*, 138: 111-16.

Río, D.C. and Caballero, J.M. 2008. Variability and classification of olive cultivars by fruit weight, flesh/stone ratio and oil percentage. Acta Hort. ISHS), 791: 39-44.

Sheidaia, M., Noormohammadib, Z., Dehghania, A., Parvinia, F., Hoshiar-Parsiana, H. and Hosseini-Mazinanic, M. 2010. Intra-specific morphological and molecular diversity in brown olive (*Olea cuspidata*) of Iran. *Sci. Asia*, 36: 187-193.

Singh, R., Rana, H.S. and Chadha, T.R. 1986. Studies on physico-chemical characteristics of some olive (*Olea europaea* L.) cultivars. In: T.R. Chadha, V.P. Bhutani, and J.L. Kaul (eds. Advances in research on temperate fruits. UHF, Nauni, Solan, p. 55-59.

Verma, M.K., Lal, S., Mir, J.I., Bhat, H.A., Sheikh, M.A. 2014. Genetic variability among 'Kashmiri Nakh' pear (*Pyrus pyrifolia*): A local variety grown in North- Western Himalayan region of India. *African J. Biotechnol.*, 13(33): 3352-3359.

Verma, N., Shaheen, R., Yadav, S.K. and Singh, A.K. 2012. Olive (*Olea europea* L.) Introduction in India: *Issues and Prospects. Vegetos*, 25(2): 44-49.

How to cite this article:

Lal, S., O.C. Sharma, D.B. Singh, S.A. Rather, B.A. Padder and Qureshi, I. 2017. Genetic Divergence of Horticultural Traits among Olive (*Olea europea* L.) Genotypes Grown in Temperate Climate. *Int.J.Curr.Microbiol.App.Sci*. 6(8): 2120-2130.
doi: https://doi.org/10.20546/ijcmas.2017.608.252