

## MORPHOLOGICAL, PHENOLOGICAL CHARACTERIZATION AND ADAPTABILITY OF EXOTIC OLIVE CULTIVARS IN DISTRICT CHAKWAL, PAKISTAN

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The present study was carried out to characterize the exotic olive cultivars on morphological as well as phenological basis and to assess their adaptability in Pothwar (Chakwal area) climatic condition of Pakistan. Majority of the parameters indicated significant variability between the cultivars and positive significant correlation were obtained between the parameters. Cultivars *Ottobratica* and *Arbequina* could be used for pollination purpose against maximum cultivars due to the longest flowering duration. Maximum fruit set percentage was recorded in cultivar *Arbequina* (5.49%) while poor fruit set was observed in cultivar *Koroneiki* (1.15%) with the mean of 2.66 for all cultivars. Maximum yield per plant was obtained from the cultivar *Coratina* (22kg) while minimum was recorded from the cultivar *Leccino* (2.5kg) with mean of 10.54kg. It is concluded from the correlation that bold size cultivars like *Coratina*, *Gemlik*, *Jerboui* and *Nabali* could be recommended for projection of olive industry in Pakistan under the climatic condition of Chakwal as fruit set percentage has positive correlation with fruit weight. The grouping of above mentioned cultivars in bi-plot on the basis of oil percentage, fruit set percentage and yield per tree also confirmed the recommendation of cultivars. Overall the trait of final fruit set percentage showed the greatest variability among all the traits among all the cultivars. Five cultivars included *Coratina*, *Gemlik*, *Nabali*, *Picholine* and *Jerboui* were most suitable for oil and yield production under the climatic condition of Pothwar, Pakistan.

**Keywords:** Germplasm, *Olea europaea*, edible oil, cultivar screening, agro-climate, genetic diversity.

### INTRODUCTION

The olive (*Olea europaea* L.) is an important species and evergreen fruit tree with premium quality oil in the Mediterranean region (Estruch *et al.*, 2013; Loumou and Giourga, 2003). Olive oil is characterized with high level of polyphenol, oleuropein, antioxidants and unsaturated fatty acids that reduces, coronary artery, cardiovascular disease and cancer with antimicrobial and antiviral effect. (Fabiani, 2016; Kalogeropoulos and Tsimidou, 2014; Malik and Bradford, 2006). The main olive oil production comes from Spain (more than 1.3 million tons per annum) and all European countries contribute about 78% of olive oil in the world. (FAOSTAT, 2016).

Pakistan is importing the edible oil and ranked fourth from edible oil importing country by importing 75% of edible oil (Syed, 2014). The import bill of Pakistan is increasing every year at alarming rate and last year (2016-17) the bill was Rs. 284.546 billion (Anonymous., 2017). The demand is increasing due to increase in population, per capita consumption and less oil seed crop production (Abdul Rashid, 2018). Pakistan is characterized with diverse environmental conditions, almost all type of horticultural crops are successfully cultivated. Olive has longer history in Mediterranean climatic region since 3000BC (Connor, 2005). In last 5-10 years olive cultivation has spread on extensive

area including Pothwar and up till now cultivation of olive has been completed on more than 3,166 acres by the funded projects of provincial government, government of Punjab, Pakistan. Under the project of olive promotion (federal government) olive has been cultivated on approximately 2,800 acres on all districts of KP, Pothwar, FATA and Baluchistan (PARC, 2018).

Olive fruit yield, oil production and quality is dependent on genotype but specific environmental conditions and transfer of genotype from one area to another area contributes a large towards successful commercial activity (Chunjiang *et al.*, 2018; Michelakis, 2002; Bignami *et al.*, 1994). Morphological, phenological and fruit trait study has vital role in screening of suitable cultivars at specific location (Youssef *et al.*, 2011). In Pakistan, very less number of studies has been made on different aspects for investigation of exotic olive germplasm with diverse origin. Hence, major aim of the study was to gather the information on the behavior of genotype and to find out the most suitable olive cultivars for Pothwar agro-climatic condition of Pakistan regarding fruit productivity, oil quality and quantity.

### MATERIALS AND METHODS

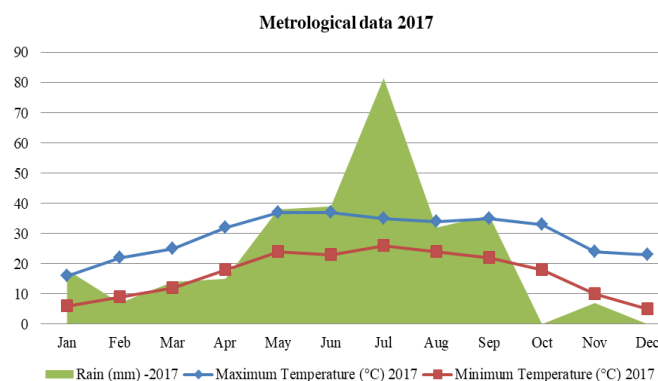
The experiment was performed in Pothwar agro-climatic condition of Pakistan in district Chakwal at Izhar Olive Farm

located at (32° 46'33 N and 72° 42' 03 E) 460 m above the sea level. The climate of the study site was arid to semi-arid with average precipitation during the last six years (2012-17) was 902 mm with the maximum average temperature during summer (June) was 37.66°C and average minimum temperature during January was 3.47°C. Maximum rainfall (444 mm) was observed in monsoon season (July to September). The driest periods with average rainfall were April to May (126 mm) and October to January (109 mm) as mentioned in Table 1. The metrological data was recorded through local weather station (Sensovant, Spain) installed at site.

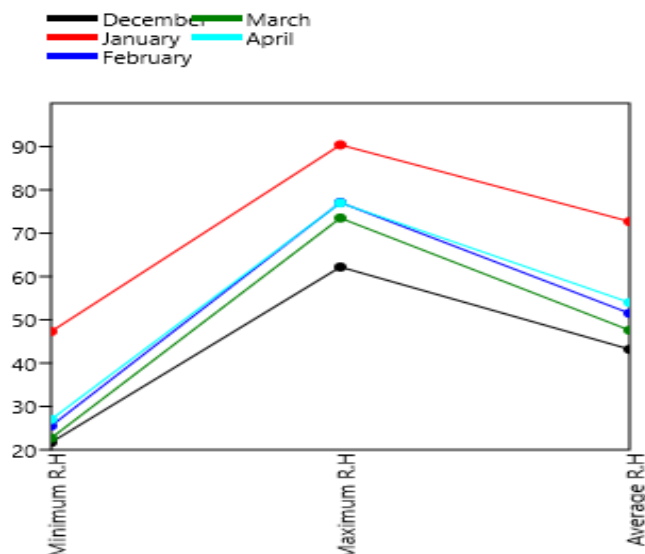
**Table 1. Average maximum temperature (°C), average minimum temperature (°C) and rainfall (mm) during 2012-17 at Izhar Olive Farm, Chakwal.**

	Minimum Temperature (°C)	Maximum Temperature (°C)	Rainfall (mm)
January	3.47	17.24	16.58
February	6.53	19.72	69.58
March	10.69	23.95	84.55
April	15.69	30.33	75.02
May	20.46	35.94	51.95
June	23.70	37.66	105.33
July	24.28	34.56	205.03
August	24.00	34.04	134.78
September	21.87	33.64	65.33
October	17.18	30.65	29.17
November	10.14	24.02	19.50
December	5.67	20.09	45.50

The study was conducted during 2017 so the detailed metrological data has been recorded for each month of the years (Fig. 1) specially the most important phenological stage (December 2016 to April 2017, Fig. 2). The metrological data was recorded with weather station installed at site.



**Figure 1. Month wise average maximum temperature (°C), minimum temperature (°C) and Rainfall (mm) for the year 2017 at Izhar Olive Farm, Chakwal, Pakistan.**



**Figure 2. Month wise minimum and maximum temperatures (°C), and average relative humidity (%) during December 2016 to April 2017 at Izhar Olive Farm, Chakwal.**

All the cultural practices from pruning to harvest were same for the plants of selected nineteen olive cultivars (Table 2) having uniform shape and canopy with open centre. The plant to plant and line to line distance was 6m x 6m. The soil was characterized sandy loam in texture with 8.1 pH and poor organic matter (0.55%). Plants were irrigated through drip irrigation system.

**Table 2. Selected olive cultivars under study planted at Izhar Olive Farm Chakwal, Pakistan.**

Cultivar name	Origin	Use
Coratina	Italy	Oil
Chemlali	Tunisia	Oil
Picholine	France	Dual
Jerboui	Tunisia	Dual
Ascolana	Italy	Table
Chetoui	Tunisia	Oil
Frantoio	Spain	Oil
Ottobratica	Italy	Oil
Earlik	Unknown	Table
Leccino	Italy	Oil
Moraiolo	Italy	Oil
Manzanilla	Spain	Table
Pendolino	Italy	Oil
FS-17	Unknown	Table
Nabali	Palestine	Table
Gemlik	Turkey	Dual
Souri	Palestine	Table
Arbequina	Spain	Oil
Koroneiki	Greece	Oil

The morphological data was collected for various parameters (Table 3) including plant height (meter rod), tree canopy, stem girth (measuring tape) and leaf size (LI-3000, LI-COR, Lincoln, NE, USA). The tree canopy was calculated by using the formula.

$$V(m^3) = \frac{\pi}{4} \cdot d^2 \cdot h$$

where CV= Canopy volume,  $\pi= 3.14$  h = Canopy height and d = Canopy diameter (Agostino *et al.*, 2007).

**Table 3. Codes for fruit traits, phenological and morphological parameters used under multivariate analysis for nineteen olive cultivars planted at Izhar Olive Farm Chakwal, Pakistan.**

Parameters	Code
Plant height (m)	PH
Tree canopy (m <sup>3</sup> )	TC
Stem girth (cm)	SG
Leaf size (cm)	LS
Number of panicles	NP
Number of flower	NF
Staminate flower (%)	SF
Pistillate flower (%)	PF
Final fruit set (%)	FFS
Fruit size (cm)	FS
Fruit weight (g)	FW
Stone weight (g)	SW
Flesh weight (g)	FLW
Yield per tree (kg)	YPT
Oil (%)	OP

Ten fully matured expanded leaves were selected for the measurement of leaf area with the help of leaf area meter (LI-COR, LI-3100 C). Total duration of flowering was calculated from opening up to full bloom. The phenological data (staminate flowers, pistillate flowers and fruit set percentage) were calculated from four randomly selected uniform branches from each side of canopy. Total yield (kg/tree) was determined at the time when fruit reached at maturity (Ferreira, 1979) with the help of electric olive harvester (Fig. 3). Fresh fruit weight (g), stone weight (g) with the help of electric balance (range 0.1 g to 1 kg) and fruit size (cm) with the help of digital vernier caliper were measured. Oil percentage was examined by using Soxhlet oil extraction apparatus on fresh weight basis (AFNOR, 1981).

**Statistical analysis:** The experiment was performed according to randomized complete block design (RCBD) with three replications. Minimum, maximum, means, standard deviations, standard error and cumulative variance were determined for fifteen parameters of nineteen olive cultivars at the 5% significance level (SAS, 2005). Further, data was analyzed by cluster analysis (UPGMA), PCA and dendrogram through XLSTAT, 2014 (v.5.03) statistical software.



**Figure 3. Electric olive harvester.**

## RESULTS AND DISCUSSION

**Morphology, reproductive and fruit traits:** All the nineteen exotic olive cultivars were studied for total duration of flowering (from opening up to full bloom). The results depicted in Table 4 showed that cultivars Picholine, Chetoui, Ottobratica, Nabali and Arbequina produced the earliest flowering on 2<sup>nd</sup> of April, closely followed by Jerbouai, Earlik, Moraiolo, and Koroneiki with the longest flowering duration in Ottobratica and Arbequina while shortest duration was observed for Ascolana. It was concluded that two cultivars Ottobratica and Arbequina can be used for pollination purpose against maximum cultivars. Our findings are in accordance with the results of Kartas *et al.* (2015) and Lavee (1985) who reported that inflorescence development and full anthesis take time. Total perfect flower per inflorescence, anthesis period, total perfect flower per shoot differ with the variation of genotype. They found that inflorescence grow in slow speed and it may take 4 to 6 weeks from bud opening to initial anthesis similar to our finding. Our results are also in harmony with Fabbri *et al.* (2004) who reported that duration of anthesis may be extended (2-3 days) in single inflorescence, (5-6 days) on single tree and may vary up to (10-15 days) in an area. The duration of flowering and anthesis is highly dependent upon genotype and warmer or cooler climatic conditions.

The results for means, standard error, standard deviation, coefficient of variance, maximum and minimum values showed in table 5. All the parameters showed the significant variability specially, SF, TC, NF, NP and YPT parameters. However, FS, FW, FLW and OP parameters depicted very low variability. In general, the greatest variability found in SF percentage (25.28%).

The Table 5 showed that maximum number of panicle per branch (35) was recorded in cultivar Chemlali and minimum (9.13) in Moraiolo with mean of 16.37 for all cultivars. Data regarding FFS, maximum fruit set was recorded in cultivar Arbequina (5.49 %) while poor fruit set was observed in

**Table 4. Anthesis and duration of flowering for nineteen exotic olive cultivars during the month of April, 2017 at Izhar Olive Farm Chakwal, Pakistan.**

Cultivar	Anthesis Period, April-2017																	Duration of flowering (days)
	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17		
Coratina																	13	
Chemlali																	12	
Picholine																	13	
Jerboui																	11	
Ascolana																	10	
Chetoui																	13	
Frantoio																	11	
Ottobratica																	16	
Earlik																	12	
Leccino																	11	
Moraiolo																	12	
Manzanilla																	12	
Pendolino																	11	
FS-17																	11	
Nabali																	12	
Gemlik																	12	
Souri																	11	
Arbequina																	14	
Koroneiki																	12	

**Table 5. Statistical descriptive analysis of fruit traits, phenological and morphological parameters of 19 olive cultivars planted at Izhar Olive Farm Chakwal, Pakistan.**

Sr.	Parameters	Minimum	Maximum	Mean	SD	SE	CV %
1	PH (m)	1.71	3.34	2.62	0.40	0.05	8.42
2	TC (m <sup>3</sup> )	5.52	32.88	13.53	5.36	0.71	21.70
3	SG (cm)	25.00	45.50	36.16	5.08	0.67	7.85
4	LS (cm)	1.13	5.02	2.66	0.79	0.62	10.51
5	NP	9.13	35.00	16.37	5.05	0.67	18.28
6	NF	51.50	300.30	156.12	55.75	7.38	23.25
7	SF (%)	8.30	58.40	24.63	9.73	1.29	25.28
8	PF (%)	41.60	91.70	75.36	9.73	1.29	8.27
9	FFS (%)	1.15	5.49	2.66	1.02	0.14	19.34
10	FS (cm)	1.05	2.57	1.74	0.41	0.06	2.93
11	FW (g)	0.66	7.65	2.80	1.80	0.24	5.17
12	SW (g)	0.26	1.01	0.57	0.23	0.03	7.44
13	FLW (g)	0.33	6.64	2.23	1.60	0.21	5.53
14	YPT (kg)	2.50	22.00	10.54	4.75	0.21	17.53
15	OP (%)	10.30	20.85	17.09	2.43	0.32	5.94

Koroneiki (1.15%) with the mean of 2.66 for all cultivars under study. Maximum yield per plant was obtained from the cultivar Coratina (22kg) while minimum was recorded from the cultivar Leccino (2.5kg) with mean of 10.54 kg for all the cultivars. About 31% cultivars yielded 13-18 kg fruit per plant while 36% cultivars concentrated in between 2.5-7 kg yield per plant. The mean values for plant characteristic like PH, TC, SG and were recorded as 2.62m, 13.53m<sup>3</sup>, 36.16cm, and 2.66cm, respectively. The mean values for flower characteristics like NF, SF and PF were 156.12, 24.63% and

75.36%, respectively. As well as the fruit trait were concerned the mean values for FS, FW, SW and FLW were recorded as 1.74cm, 2.80g, 0.57g and 2.23g respectively. Cultivar Coratina showed maximum oil content (21%) while minimum was recorded from the Cultivar Leccino 10.3%. The mean oil content (17.09 %) was recorded for all the cultivars. However, 79% cultivars were ranged with 17-20% oil content.

The variability which was observed in various parameters such as SF, NF, TC, FFS and YPT in olive cultivars under study has a special importance (Mnasri *et al.*, 2017; Sorkheh

*Performance of exotic olive cultivars*

and Khaleghi, 2016). Similar studies on vegetative and reproductive parameters of olive germplasm in Tunisia (Mnasri *et al.*, 2014; Hannachi *et al.*, 2008) were conducted and same results were found in our study. Both studies reported that morphological and fruit traits has important role for distinguishing the olive cultivars.

**Principal component analysis (PCA):** In our experiment we analyzed the variables through principal component analysis (PCA) that is mostly used before the cluster analysis for the purpose of relative significance of the classification of the variables (Berdahl *et al.*, 1999). The results from Table 6 depicted that the first five principal components has significant contribution and eigen values of first, second; third, fourth and fifth axis have the values 29.52, 48.45, 64.69, 75.36 and 82.15% and accounted 29.52, 18.93, 16.24, 10.67 and 6.79%, respectively.

Through judgment of relative magnitude of the first PC factors, it is concluded that FW, FLW, FS, SW, and YPT parameters were important traits for the selection of cultivar in cluster. (Sorkkeh and Khaleghi, 2016). In the 2<sup>nd</sup> principal component PH, SG and TC have better role for classification of olive cultivars. In the 3<sup>rd</sup> PC traits of SF and LS contributed well, while NP and NF in 4<sup>th</sup> PC had comparatively high Eigen values. In fifth principal component OP and PF depicted the satisfactory contribution.

**Table 6. Estimates of accumulative variance, eigen values and first five PC factors for 15 parameters studied on 19 olive cultivars planted at Izhar Olive Farm Chakwal, Pakistan.**

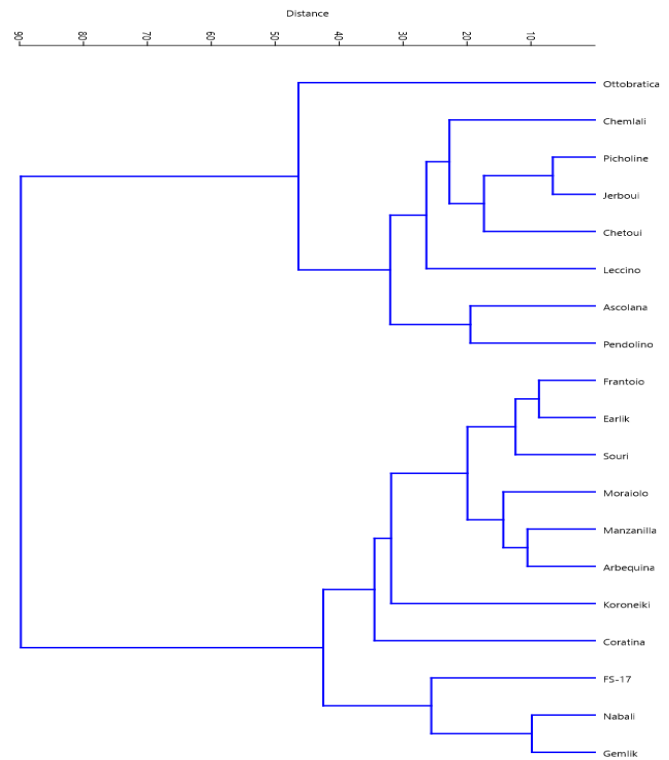
Principal Component	PC1	PC2	PC3	PC4	PC5
<b>Eigen values</b>	4.428	2.840	2.436	1.600	1.019
<b>Accumulated variance (%)</b>	29.520	48.453	64.691	75.361	82.156
<b>Traits</b>	<b>Factor</b>				
PH	0.120	0.504	-0.077	0.199	-0.047
TC	0.193	0.478	-0.102	0.130	-0.011
SG	0.120	0.502	-0.061	0.217	-0.019
LS	0.102	0.351	0.232	-0.168	0.197
NP	-0.016	-0.159	-0.283	0.610	-0.018
NF	-0.201	-0.126	-0.240	0.505	-0.126
SF	-0.266	0.085	0.430	0.124	-0.279
PF	0.266	-0.085	-0.430	-0.124	0.279
FSP	0.196	-0.023	-0.314	-0.328	-0.526
FW	0.410	-0.153	0.206	0.174	-0.079
FS	0.393	-0.100	0.255	0.104	0.019
SW	0.363	-0.156	0.232	0.087	-0.127
FLW	0.405	-0.148	0.196	0.182	-0.069
OP	0.154	-0.079	-0.099	0.014	0.620
YPT	0.248	0.013	-0.332	-0.145	-0.313

The PCA showed significant degree of variability about 82.15 % for first five principal components (Mnasri *et al.*, 2017; Yilmaz *et al.*, 2017) which assured that principal component

analysis were highly descriptive of the main parameters of the data.

**Correlation matrix:** Correlation matrix of fifteen parameters analyzed through principal component analyses (Table 7) showed that YPT highly positive correlation with FFS and positive significant correlation with PF while it had significant negative correlation with SF. NF has highly positive correlation with NP and negative correlation with LS. The most important parameter for potential adaptability of olive genotype in Pakistan might be FFS which has highly significant correlation with FW and negative correlation with NF. From the data it could be concluded that bold size fruit cultivars had better opportunity for adaptation as FFS had highly significant positive correlation with fruit weight. These correlations are in accordance with previous reported results (Hannachi *et al.*, 2008; Cantini *et al.*, 1999). From the Table 7 of correlation, it had resulted that plant vegetative parameters like PH, TC, SG and LS had positive correlation with each other.

**Cluster analysis:** The cluster analysis was obtained for 19 olive cultivars having 15 different parameters in the form of dendrogram (UPGAMA analysis) presented in Figure 4.



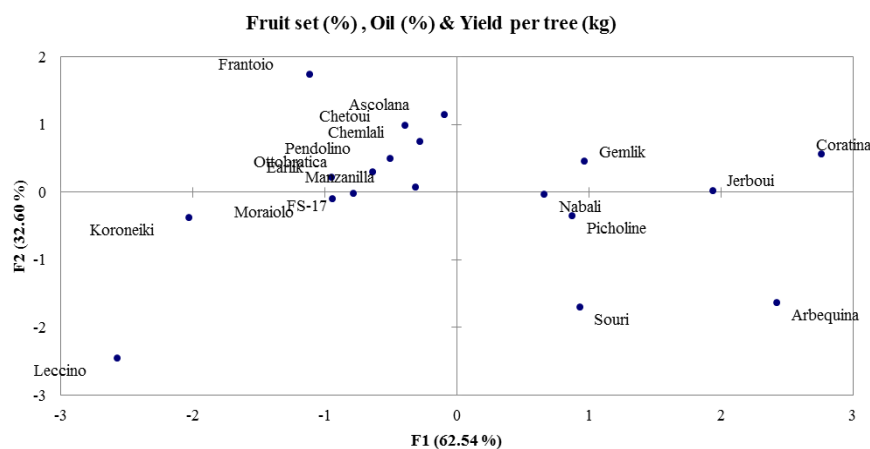
**Figure 4. Dendrogram of the 19 olive cultivars derived from UPGMA analysis planted at Izhar Olive Farm Chakwal, Pakistan.**

The results showed that there were two groups having three sub groups in each main group on the basis of all variables.

**Table 7. Variable correlation matrix analyzed through PCA for 15 traits studied on 19 olive cultivars planted at Izhhar Olive farm Chakwal, Pakistan.**

	PH	TC	SG	LS	NP	NF	SF	PF	FFS	FW	FS	SW	FLW	OP
TC	0.793**													
SG	<0.0001	0.827**												
LS	<0.0001	<0.0001	0.798**											
NP	0.367*	0.430*	0.364*											
NF	0.005	0.001	0.005	-0.402*										
SF	-0.008	-0.018	-0.033	0.002	0.647**									
PF	0.952	0.897	0.810	-0.347*	0.109									
FFS	-0.115	-0.207	-0.082	0.008	0.187	0.421								
FW	0.394	0.123	0.543	0.008	0.187	0.421	-1.000*							
FS	-0.049	-0.202	-0.029	0.124	-0.177	0.109	0.417*	0.417*						
SW	0.715	0.132	0.828	0.359	0.187	0.421	<0.0001	<0.0001						
FLW	0.049	0.202	0.029	-0.124	0.177	-0.109	0.421	<0.0001	0.417*					
OP	0.715	0.132	0.828	0.359	0.187	0.421	<0.0001	<0.0001	0.417*					
YPT	0.035	0.161	0.026	-0.100	-0.076	-0.154	-0.417*	0.417*	0.417*					
	0.796	0.233	0.850	0.461	0.575	0.253	0.001	0.001	0.001	0.164				
	0.024	0.130	0.044	0.057	0.054	-0.293*	-0.265*	0.264*	0.164	0.164				
	0.860	0.334	0.743	0.673	0.688	0.027	0.047	0.047	0.224	0.224				
	0.036	0.157	0.053	0.221	-0.056	-0.362*	-0.214	0.214	0.054	0.882**				
	0.788	0.244	0.698	0.099	0.677	0.006	0.109	0.109	0.690	<0.0001				
	-0.026	0.056	-0.040	0.123	-0.039	-0.267*	-0.152	0.152	0.179	0.831**	0.777**			
	0.845	0.678	0.767	0.362	0.773	0.045	0.260	0.260	0.184	<0.0001	<0.0001			
	0.031	0.138	0.056	0.046	0.067	-0.289*	-0.274*	0.273*	0.157	0.996**	0.873**	0.782**		
	0.820	0.307	0.681	0.736	0.622	0.029	0.039	0.039	0.244	<0.0001	<0.0001	<0.0001		
	-0.029	0.011	0.009	0.043	0.080	-0.050	-0.258	0.258	0.026	0.190	0.201	0.211	0.182	
	0.832	0.936	0.945	0.751	0.553	0.709	0.052	0.052	0.845	0.156	0.133	0.114	0.176	
	0.174	0.221	0.135	0.027	0.079	-0.028	-0.449*	0.449*	0.676**	0.214	0.232	0.252	0.202	0.263*
	0.196	0.099	0.316	0.843	0.557	0.838	0.000	0.000	<0.0001	0.110	0.083	0.059	0.132	0.048

Upper values indicated Pearson's correlation coefficient; Lower values indicated level of significance at 5% probability.\* = Significant (P < 0.05); \*\* = Highly significant (P < 0.01)



**Figure 5. Bi-plot showing projection and relationship between 19 olive cultivars on the basis of fruit set (%), oil (%) and yield per plant (kg).**

Main Group-I included Gemlik, Nabali, FS-17, Coratina, Koroneiki, Arbequina, Manzanilla, Moraiolo, Souri, Earlik and Frantoio. Main group-II contained Ottobratica, Chemlali, Picholine, Jerboui, Chetoui, Leccino, Ascolana and Pendolino. The largest sub group included six cultivars like Frantoio, Earlik, Souri, Moraiolo, Manzanilla, and Arbequina which had come under main group-I. While in main group-II the largest subgroup consisted of seven cultivars including Chemlali, Picholine, Jerboui, Chetoui, Leccino, Ascolana and

Pendolino. However, Ottobratica has shown the distinguish feature in main group-II in comparison with other cultivars. Our results were similar as reported in some previous studies (Mnasri *et al.*, 2014; Trentacoste and Puertas, 2011). It is concluded that dendrogram of 19 cultivars split into two main groups and sub groups based on vegetative, reproductive and fruit parameters proved that the traits under study had significant role in differentiation of olive.

**The cultivar vector view of the bi-plot:** The bi-plot based on yield, oil percentage and fruit set percentage showed that 95.15% of total variation of the olive cultivars (Fig. 5). The maximum projection was detected by olive cultivar Frantoio and the lowest for Manzanilla. Earlik, Ottobratica, Pendolino, Chemlali, Chetoui and Ascolana were correlated positively while FS-17, Koroneiki, Leccino and Moraiolo were correlated negatively. From the Figure 4 it was also concluded that the greatest diversity was found in Frantoio, Arbequina, Leccino and Souri cultivars. Rests of other cultivars were moderately correlated to each other containing positive and negative values. On the basis of mentioned three parameters, Coratina, Gemlik, Jerbouai, Picholine and Nabali could be recommended for projection of olive industry in Pakistan under the climatic condition of Chakwal.

**Conclusion:** Climatic conditions of Pothwar are suitable for olive production but unfortunately there is lack of local olive germplasm. It was a dire need to find out the suitable olive cultivars in existing agro-climatic condition of Pothwar to established successful olive industry in Pakistan on sound footage. A detailed research study was carried out on morphology, phenology and fruit traits on large number of cultivars. It is concluded that bold size fruit cultivars like Coratina, Nabali, Gemlik, Picholine and Jerbouai have better adaptation ability then small size fruit cultivars having strong correlation between fruit set percentage and fruit size. The oil percentage and fruit yield were also found better in these cultivars. The plantation of these cultivars on large scale will be helpful for farming community which will improve the socio-economic status of public at large. Consequently, intervention in olive business will be able to reduce the huge bill of Pakistan incurred on import of edible oil. However detailed studies are required for selection of olive cultivars in whole region of Pothwar and other areas of Pakistan.

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