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ADAPTABILITY, AGRONOMIC AND YIELD PERFORMANCE OF EXOTIC OLIVE (*OLEA EUROPAEA*) CULTIVARS IN POTHWAR REGION OF PAKISTAN

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Abstract

This study was conducted under arid sub-tropical conditions of Pothwar region to evaluate the adaptability of eighteen olive cultivars and selection of suitable genotypes on the basis of fruit yield and oil production. Longest period for pollen donation was observed in olive cultivars Ottobratica, Frantoio, and Hamdi. The shortest pollen production or dissemination time was observed in the cultivars Azerbaijan and Nocellera. Tree canopy, staminate flower, number of flowers per twig, initial and final fruit set percentage, number of shot berries and yield per plant depicted highly significant variation among the cultivars. However, leaf size, pistillate flower, fruit size, fruit weight and oil recovery percentage showed less variation among the cultivars. Final fruit set percentage showed the greatest variability among all the traits in different cultivars. According to the results of study, five olive cultivars including Coratina, Gemlik, Moraiolo, Nabali and Hamdi were found most suitable for oil and fruit yield under the climatic condition of Pothwar region of Pakistan.

Key words: Adaptability, Arid region, Morphological, Phenology, *Olea europaea*, Pothwar.

Introduction

Olive (*Olea europaea* L.) is an important evergreen fruit tree and is famous for special oil characteristics and nutritional benefits for human health (Conde *et al*., 2008; Estruch *et al*., 2013). According to a report, Spain is the leading olive oil producer with an annual production of 1.30 million tons. 78% of the olive oil is produced in the European countries (Anon., 2016). Olive oil that is obtained by the cold press method has premium quality, nutrition, and dietary characteristics such as unsaturated fatty acids and antioxidants which are useful against cardiovascular diseases and cancer in the Mediterranean humanities (Mercedes, 2004; Parkinson & Russell, 2014).

Pakistan is the fourth largest edible oil importing country in the world. Pakistan imports 70% of the total edible oil to fulfill the requirement in the country and spends a lot of money in lieu of import bill. Only 30% of the total oil requirement is fulfilled by domestic production (Kiran, 2017). The import bill of edible oil during the fiscal year 2016-2017 was 284.546 billion rupees (2.710 billion US$) that is increasing at an alarming rate (Anon., 2017). This increasing trend is because of continuous increase in the population and less oilseed crop production. The increase in per capita consumption of edible oil was jumped from 17 to 18 Kg during the last five years (Abdul Rashid, 2018). To meet the increasing oil demands there are two ways, 1) increase the area and production of oil seed crop through improved Cultivars, and 2) introduction of new oil-producing crops such as olive. Pakistan is bestowed with distinct environmental conditions. The country is diversified with mountain, flat land, arid and semi-arid areas. Down in the center is a flat fertile plain fed by the Indus river and its largest canal system. It has scanty and erratic rainfall and range of extreme temperatures, undulating and terraced land such as Pothwar (Rashid, 1995). Olive has a long history in the Mediterranean climatic region with signs of recent admixture with wild olive. However, the origin of cultivated olive remained unclear (Concepcion *et al*., 2015). Turkey, Morocco, Syria and Egypt have olive production but yield is less due to lack of adoption of modern olive production practices (El-Kholy *et al*., 2012). Although Pakistan has no longer history for olive cultivation, however during the last decade olive cultivation has gained popularity because of its great socio-economic importance. More than 3,166 acres have been brought under olive cultivation in Pothwar region and 2,800 acre (280,004 plants) was cultivated other than Pothwar region under the Olive Promotion Project supported by Federal Government, Pakistan (Anon., 2018).

Micro-environmental, ecological and local adopted cultivation techniques affect productivity (Cimato *et al*., 1990; Bignami *et al*., 1994; Michelakis, 2002). In-depth study on characterization of olive cultivars is very important as each cultivar has specific agronomic characteristics, and different production levels at a specific location especially phenols and oil profiling are genotypic features (Grati-Kamoun *et al*., 2006; Youssef *et al*., 2011; Fahad *et al.*, 2017).

In Pakistan little information is available regarding the performance of exotic olive cultivars. Thus, before the establishment of olive industry in Pakistan, the performance of exotic cultivars requires investigations regarding its phenological, morphological and pomological characteristics based on the agronomic performance descriptors (Damigella, 1960; Barranco & Rallo, 1985; Cantini *et al*., 1999; Barranco *et al*., 2000; Ouazzani, 2014). The main objective of this study was to collect information regarding the vegetative and reproductive behavior of exotic cultivars and selection of suitable cultivars for Pothwar region of Pakistan on the basis of fruit and oil productivity.

Materials and Methods

Location with metrological data: The research trial was conducted during 2017 at Barani Agricultural Research Institute (BARI) Chakwal Northern Punjab, Pakistan (320 92'82 N and 720 7201 E) at an altitude of 575 m. The climate of the area is arid to semi-arid characterized with average annual precipitation (772mm), maximum average temperature during summer (36-38°C) and average minimum temperature during January (1.7°C). Maximum rainfall (408 mm) was received in monsoon season from July to September. The driest period during the years ranged from May to June with average rainfall 110 mm and from October to January with an average rainfall less than 70 mm. Total rainfall (817 mm) was received in the year of 2017 (Anon., 2017). The detail of the metrological data measured with the weather station (HOBO) installed at Soil and Water Conservation Research Institute, Chakwal during the observation period is as follows (Figs. 1-2).

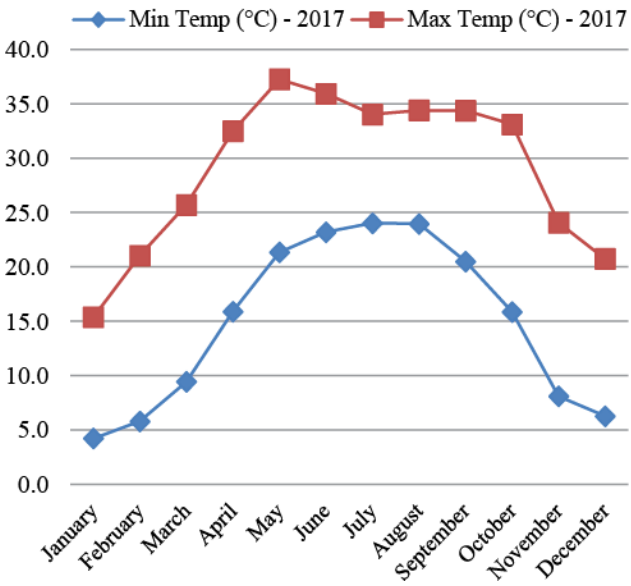

Fig. 1. Maximum and minimum temperature (°C) for the year of 2017 at BARI, Chakwal, Pakistan.

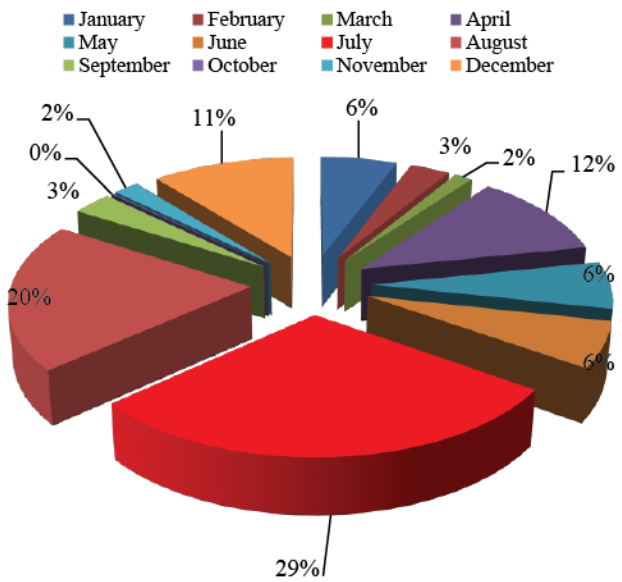

Fig. 2. Month wise rainfall distribution (percentage) for the year 2017 at BARI, Chakwal, Pakistan.

Plant material: Eighteen exotic olive cultivars were selected in this study having age from six to ten years with uniform canopy and planting geometry of 6m x 6m (Table 1). There was sandy loam soil having organic matter less than 1% with pH of 8.1. The plants were pruned to a central open shape. All the cultural practices (irrigation, fertilization, hoeing, and weeding) were kept same for all the cultivars. Drip irrigation (HEIS) system was source for uniform irrigation to all plants.

Parameters under studies: Vegetative and reproductive responses of olive cultivars were studied (Table 2). Data for tree canopy, leaf size and stem girth were measured under plant morphological parameters. Tree canopy was measured for each selected plant by using the formula:

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

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

Table 1. Name, origin and use of olive cultivars studied under Pothwar agro-climatic condition of Pakistan.

Cultivar name	Origin	Consumption
Gemlik	Turkey	Dual
Manzanilla	Spain	Dual
Frantoio	Spain	Oil
Azerbaijan	Azerbaijan	Table
Sevillano	Spain	Table
Nocellera	Italy	Table
Earlik	Israel	Table
Hamdi	Palestine	Table
Nabali	Palestine	Table
FS-17	Italy	Table
Souri	Palestine	Table
Ottobratica	Italy	Oil
Coratina	Italy	Oil
Pendolino	Italy	Oil
Leccino	Italy	Oil
Chietina	Italy	Dual
VP-1 (Correggiolo)	Italy	Oil
Moraiolo	Italy	Oil

Table 2. List of morphological, phenological, fruit traits and their codes, used in the multivariate analysis of the olive cultivars block.

Trait	Parameter	Code
Morphology	Tree canopy (m^3)	TC
	Stem girth (cm)	SG
	Leaf size (cm)	LS
Phenology	Number of panicles	NP
	Number of flower	NF
	Staminate flower (%)	SF
	Pistillate flower (%)	PF
Fruit	Initial fruit set (%)	IFS
	Number of shot berries	NSB
	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

Leaf area of each cultivar was measured from randomly selected ten fully mature expanded leaves by using a leaf area meter (LI-COR, Model NO. LI-3100 C). The total duration of flowering was estimated as the time interval between the openings of the flower to full bloom. Data regarding the percentage of staminate, pistillate flower and fruit set was calculated from four randomly selected branches from each side of the canopy. Fruits were harvested by hand and the total yield (Kg/tree) was determined at the time when the fruit reached at maturity index (Ferreira, 1979). Thirty Fresh olive fruit were randomly selected from all four side of the marked plant and fruit weight (g) was measured with the help of digital electric balance (range 0.01 g to 1kg) and fruit size (cm) were recorded with the help of digital vernier caliper and average was calculated. The stone was extracted and flesh and stone were weighed separately. Fruit of the different olive cultivars was collected and oil percentage was determined on a fresh weight basis by using Soxhlet oil extraction apparatus with hexane 60-80°C boiling point (Anon., 1981).

Statistical analysis: The experiment was laid out according to randomized complete block design with three replications. The data for eighteen Cultivars with sixteen characters were analyzed to determine minimum, maximum, means, standard deviations, standard error, cumulative variance and least significant difference (LSD) was utilized to compare the means at $p \leq 0.05$ (Anon., 2005). Data were then subjected to PCA, cluster analysis (UPGMA) and dendrogram were produced through statistical software XLSTAT, 2014 (v.5.03).

Results and Discussion

Morphology, phenology and fruit characteristics: The olive cultivars were evaluated for the flower anthesis and total duration of flowering. The results regarding the date of anthesis and total duration of flowering period were presented in Table 3. The results showed that cultivars Earlik and Ottobratica started earlier anthesis on 8th April, closely followed by Frantoio, Gemlik, Nabali, Coratina and Chietina. While the longest flowering duration was observed in Ottobratica followed by Frantoio and shortest duration was observed in Azerbaijan and Nocellera. From the data, it was concluded that Ottobratica, Frantoio and Hamdi could be used for pollination purpose due to the longer flowering duration. The date of flowering is closely associated with temperature. Our results are in accordance with the study of Koubouris *et al*., (2010) who reported that increase in temperature is positively correlated with first flowering stage.

A glance of Table 4 indicated that average initial fruit set was observed 20.16 % with maximum 35.70% in Souri closely followed Gemlik (34.50 %) while minimum initial fruit set percentage was observed in Earlik 9.20 %. As for as the final fruit set was concerned the maximum value was recorded in Moraiolo (4.73 %) closely followed by Nabali (4.14 %) and Coratina (3.91 %). While the minimum value was observed in Nocellera (0.97 %). The average value for FFS was observed at 2.46 %. The data collection was characterized by average NF of 145.66 per branch, OP 16.82 % and YPT 15.47 %. About 67 % cultivars concentrated NF 120 to 185 while 16 % have flower less than 100 and 17 % have NF greater than 200.

The 22 % cultivars have YPT more than 20 to 24 kg, 27 % fall in 15 to 19 kg and rest of all cultivars showed average yield 8 to 14 kg per plant. Overall 66 % cultivars depicted OP 16 to 20 % while minimum OP was extracted from Souri 9.75 % and the maximum OP was 22.10 % in Frantoio.

The diversity observed in different agro-morphological traits like FS, FW, and FLW in selected olive cultivars has a significant importance (Sorkheh & Khaleghi, 2016; Mnasri *et al*., 2017). Our results are in agreement with the previous study on morphological traits related to olive germplasm in Tunisia (Trigui *et al*., 2002; Grati-Kamoun *et al*., 2006; Hanachi *et al*., 2008; Mnasri *et al*., 2013; Mnasri *et al*., 2014) which described the importance of morphological fruit data for distinguishing olive cultivars.

Table 3. Flowering duration for eighteen olive cultivar under study in the month of April 2017.

Cultivar under study	Flower Anthesis Period, April-2017																Duration of flowering (days)
	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	
Earlik																	11
Manzanilla																	13
Frantoio																	15
Azerbaijan																	10
Sevillano																	12
Nocellera																	10
Gemlik																	13
Hamdi																	14
Nabali																	12
FS-17																	13
Souri																	11
Ottobratica																	16
Coratina																	13
Pendolino																	13
Leccino																	11
Chietina																	12
Correggiolo(VP-1)																	13
Moraiolo																	13

The morphological, phenological and fruit attributes indicated significant variability in all the cultivars particularly TC in morphological, SF, NF and NP in phenological, FFS, IFS, NSB and YPT in fruit traits. However, LS in morphological, PF in phenological, FS, FW and OP in fruit traits showed very little variability. Overall, the trait of final fruit set percentage showed the greatest variability among all the traits in all the cultivars closely followed by SF. It is evident from the study conducted by various scientists that fruit set per inflorescence, fruit size and yield is highly associated with genotype and prevailing environmental condition (Lavee *et al.*, 1985; Ayerza & Sibbett, 2001; Conner & Fereres, 2005)

Table 4. Descriptive statistics analysis of morphological, phenological and fruit attributes of olive cultivars.

Trait	Parameters	Minimum	Maximum	Mean	SD	SE	CV %	LSD 5%
Morphology	TC (m^3)	3.85	77.01	38.41	21.09	2.870	15.48	18.25
	SG (cm)	25.00	98.00	63.74	21.27	2.894	12.43	24.35
	LS (cm)	16.16	49.12	28.99	7.72	1.051	10.35	9.59
Phenology	NP	7.10	30.60	15.50	5.43	0.739	17.79	8.63
	NF	68.00	251.10	145.66	47.50	6.464	18.04	79.64
	SF (%)	7.60	44.30	21.30	7.34	0.999	19.34	17.98
	PF (%)	55.72	92.43	78.70	7.33	0.998	7.44	17.97
	IFS (%)	9.20	35.70	20.16	6.56	0.893	18.80	11.82
	NSB	10.63	38.13	21.79	6.55	0.891	17.64	11.81
	FFS (%)	0.97	4.73	2.46	0.88	0.120	19.49	1.48
Fruit	FS (cm)	0.94	5.08	3.18	1.44	0.196	3.10	0.51
	FW (g)	1.23	2.57	1.90	0.35	0.047	5.27	0.18
	SW (g)	0.26	1.37	0.63	0.24	0.033	7.22	0.14
	FLW (g)	0.63	4.19	2.55	1.28	0.174	5.83	0.46
	YPT (kg)	6.35	28.35	15.47	5.25	0.714	16.70	7.94
	OP (%)	9.75	22.10	16.82	2.63	0.358	6.75	3.51

Table 5. Estimates of variance, accumulative and factors of first five PC for 16 parameters studied on 18 olive cultivars.

		PC1	PC2	PC3	PC4	PC5
Eigenvalues		5.71	2.88	2.83	1.42	1.16
Accumulated variance (%)		35.6	53.6	71.3	80.1	87.4
Traits		**Factors**				
Morphology	TC	0.5560	-0.5020	0.2881	-0.4358	-0.2425
	SG	0.5588	-0.5442	0.2863	-0.4777	-0.2341
	LS	0.1939	-0.5728	-0.1675	-0.2370	0.6786
Phenology	NP	0.1420	-0.7303	0.4644	0.1307	-0.0575
	NF	-0.8147	-0.2850	0.2340	-0.2035	0.2797
	SF	-0.6784	0.1487	0.5437	-0.2928	-0.1067
	PF	0.6790	-0.1494	-0.5427	0.2927	0.1063
Fruit	IFS	0.5248	0.6303	-0.3260	-0.2530	-0.3415
	NSB	-0.4293	0.5729	-0.1884	-0.5975	0.1035
	FFS	0.2510	-0.3039	-0.7246	0.0853	-0.1174
	FS	0.8897	0.2604	0.2485	-0.0723	0.2005
	FW	0.8897	-0.0050	0.2652	0.0936	-0.0200
	SW	0.6298	0.3839	-0.1562	-0.3508	0.4035
	FLW	0.8804	0.2196	0.3089	-0.0142	0.1494
	YPT	0.0252	-0.4326	-0.7046	-0.3654	-0.3047
	OP	-0.3906	-0.2768	-0.5978	-0.1332	0.1534

The PCA indicated degree of variability of about 87% for first five principal components (Mnasri *et al*., 2017; Yilmaz *et al*., 2017) which insured that PCA plot were highly representative of the main parameters of the data

Principal component analysis (PCA): Generally, PCA used before the cluster analysis for the determination of relative importance of the classification of variables (Berdahl *et al*., 1999). The first five principal components contributed a lot and eigenvalue of first, second; third, fourth and fifth axis accounted the 35.60%, 53.60%, 71.30%, 80.10% and 87.4 % of the total variance respectively (Table 5). The result depicted that FS, FW, and FLW in fruit traits, PF in phenological trait and SG and TC in morphological traits were important parameters for the selection of cultivars in the cluster through a judgment of relative magnitude of the first PC factors (Sorkheh & Khaleghi, 2016). In the second principal component IFS, NSB and SW have better contribution for cultivars classification. The SF, NP, TC and SG parameters had comparatively high eigen factors in the third PC, While NP and PF in forth PC and LS and SW in fifth PC showed the better the contribution.

Correlation matrix: The Table 6 related to correlation matrix of sixteen different parameters analyzed through PCA indicated that FFS has a highly significant positive correlation with yield and significant correlation with PF while it has the negative correlation with SF. FS has highly significant positive correlation with fruit weight and a significant positive correlation with TC and SG. These correlations are in accordance with previously reported results (Cantini *et al*., 1999; Hanachi *et al*., 2008). However, FS had a significant negative correlation with NF and NSB. From the Table 6 of correlation matrix, it had concluded that oil content had a positive correlation with YPT.

Table 6. Correlation matrix of variables obtained from PCA for 16 parameters studied on 18 olive cultivars.

	TC	YPT	OP	SG	LS	NP	NF	SF	PF	IFS	NSB	FFS	FW	FS	SW	FLW
TC	1.00															
YPT	0.18	1.00														
	0.47															
OP	-0.28	0.51*	1.00													
	0.26	0.04														
SG	0.93**	0.30	-0.22	1.00												
	0.00	0.24	0.37													
LS	0.27	0.27	0.26	0.33	1.00											
	0.28	0.28	0.30	0.18												
NP	0.51*	-0.04	-0.01	0.53*	0.21	1.00										
	0.03	0.86	0.96	0.02	0.39											
NF	-0.20	-0.06	0.23	-0.20	0.17	0.14	1.00									
	0.42	0.82	0.36	0.42	0.50	0.57										
SF	-0.20	-0.30	-0.04	-0.15	-0.27	-0.03	0.62**	1.00								
	0.43	0.23	0.87	0.54	0.28	0.91	0.01									
PF	0.20	0.30	0.04	0.16	0.27	0.03	-0.62**	-1.00**	1.00							
	0.43	0.23	0.87	0.54	0.28	0.90	0.01	0.00								
IFS	0.07	0.16	-0.15	0.05	-0.37	-0.500*	-0.76**	-0.34	0.34	1.00						
	0.78	0.54	0.55	0.84	0.14	0.04	0.00	0.16	0.16							
NSB	-0.33	0.05	0.24	-0.35	-0.21	-0.59*	0.33	0.36	-0.36	0.32	1.00					
	0.19	0.83	0.34	0.15	0.41	0.01	0.18	0.14	0.14	0.19						
FFS	0.08	0.66**	0.27	0.06	0.28	-0.18	-0.31	-0.490*	0.490*	0.12	-0.29	1.00				
	0.76	0.00	0.28	0.81	0.27	0.47	0.21	0.04	0.04	0.63	0.25					
FW	0.38	-0.27	-0.50*	0.41	0.14	0.01	-0.67**	-0.39	0.39	0.48*	-0.23	-0.02	1.00			
	0.12	0.27	0.03	0.09	0.59	0.97	0.00	0.11	0.11	0.04	0.37	0.95				
FS	0.47*	-0.15	-0.39	0.52*	0.10	0.30	-0.71**	-0.43	0.43	0.37	-0.48*	0.04	0.88**	1.00		
	0.05	0.55	0.11	0.03	0.71	0.23	0.00	0.07	0.07	0.13	0.05	0.87	0.00			
SW	0.19	-0.06	-0.17	0.16	0.22	-0.25	-0.47*	-0.40	0.40	0.57*	0.21	0.10	0.70**	0.42	1.00	
	0.46	0.80	0.51	0.52	0.38	0.32	0.05	0.10	0.10	0.01	0.41	0.70	0.00	0.08		
FLW	0.40	-0.30	-0.54*	0.43	0.11	0.06	-0.66**	-0.36	0.36	0.43	-0.29	-0.04	0.99**	0.91**	0.59**	1.00
	0.10	0.24	0.02	0.07	0.66	0.82	0.00	0.14	0.14	0.07	0.24	0.89	0.00	0.00	0.01	

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

Cluster analysis: The results of cluster analysis were obtained in the form of dendrogram from UPGAMA analysis carried out on sixteen morphological, phenological and fruit parameters related to 18 exotic olive cultivars under study (Table 1). From the dendrogram (Fig. 3) it showed that there were two main groups with four sub groups (sub group I, sub group II, sub group III and sub group IV). The sub group-I includes Earlik, Pendolino, Leccino and Ottobratica while sub group-II consists of Nocellera, Chietina, VP-1, Moraiolo and Coratina. The sub group-III (the largest group) included Manzanilla, Frantoio, Azerbaijan, Hamdi, FS-17 and Nabali, while the sub group-IV that is the smallest group contained only three cultivars Sevillano, Souri and Gemlik.

By comparison of the dendrogram (Fig. 3) based on morphological traits showed a positive and highly significant correlation (Garcia-donas, 2001; Mulas & Porceddu, 2006; Hanachi *et al*., 2008; Zaher *et al*., 2011). The similar results were observed from the study of Trentacoste & Puertas, (2011) on the studied parameters for the phenotypic variability especially for fruit weight and oil content. Furthermore, dendrogram of 18 cultivars under examination were divided into four groups based on morphology data that proved the parameters under study have significance to differentiate the olive cultivars.

In some previous studies dendrogram was constructed and classified olive cultivars on the base of morphological traits and found good segregation among the olive population (Paula *et al*., 2005; Hanachi *et al*., 2008; Hanachi *et al*., 2012; Mnasri *et al*., 2014). However, Grati-Kamoun *et al*., (2006) found poor results for morphological traits due to small number of polymorphism detected as it is environmentally dependent.

Cultivars vector view of the bi-plot: Bi-plot based on the correlation of oil and yield characteristics (Fig. 4) showed 100 % of total variation of the olive cultivars from the table 5. The highest projection was observed for olive Cultivar Souri and the lowest for Manzanilla, Ottobratica and Coratina. Hamdi and Nabali were correlated positively. Nocellera, Sevillano, VP-1 and Chietina were negatively correlated while rest of olive cultivars were moderately correlated containing positive and negative values. Souri and Frantoio were the most diverse olive cultivars regarding oil and yield characteristics studied among all cultivars.

As for as the grouping is concerned there was positively quadrate in the group of Hamdi and Nabali and in between Gemlike and Moraiolo. cultivars Nocellera and Sevillano has the same group but were the negatively correlated.

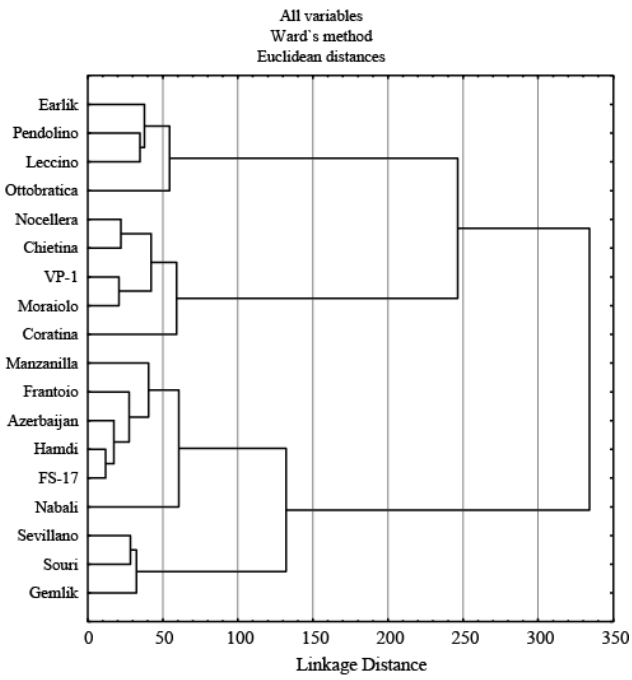

Fig. 3. Dendrogram of the eighteen exotic cultivars derived from UPGMA analysis and dissimilarity matrix of all the parameters under study.

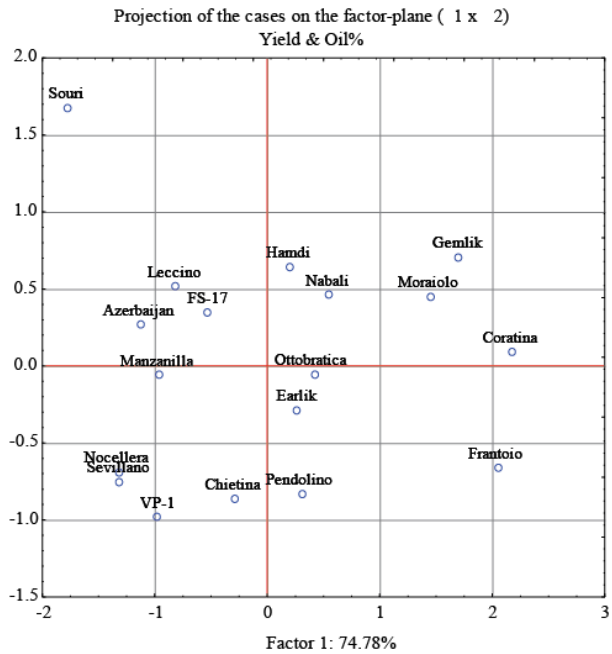

Fig. 4. Diagram showing projection and relationship between 18 olive cultivars based on yield per tree and oil (%).

Conclusion

Pakistan is bestowed with diverse agro-climatic condition. Olive can be grown on barren marginal land of Pothwar but unfortunately there was lack of in depth scientific study on exotic olive cultivars regarding it's morphological, phenological and fruit traits. According to the best of our knowledge this is the first report for the selection of adaptable olive cultivars performed with morphological descriptor on olive germplasm. Our results suggested that five olive cultivars viz-a-viz Coratina, Moraiolo, Gemlik, Nabali and Hamdi were suitable for oil and fruit yield for Pothwar region on the basis of fruit set percentage, fruit yield and oil productivity. On one hand, our study on morphological diversity among olive cultivars will serve as a reliable tool for conservation and preservation strategies of olive germplasm and on another hand it will be helpful in improving the oil quantity and quality and market opportunities. However, for perfect and most reliable knowledge qualitative traits and molecular marker could be used in future studies. It is also recommended cultivar specific study for phenological traits in whole districts of Pothwar including numerous cultivars for better results orientation.

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