Pak. J. Biotechnol. Vol. 21(2),494-500, 2024. http://doi.org/10.34016/pjbt.2024.21.02.953

Research Article

OPEN ACCESS

Available on http://www.pjbt.org
Pakistan Journal of Biotechnology (PJBT)
(P-ISSN: 1812-1837 and E-ISSN: 2312-7791)

MORPHOLOGICAL AND YIELD-RELATED POMOLOGICAL CHARACTERIZATION OF INTRODUCED OLIVE (*OLEA EUROPEA*) CULTIVARS IN RAINFED AREA OF POTHOWAR PUNJAB

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Article Received 19-07-2024, Article Revised 30-08-2024, Article Accepted 11-09-2024.

ABSTRACT

This study aims at pomological characterizing of 09 olive cultivars planted in the field area of Barani Agricultural Research Institute (BARI), Chakwal to estimate genetic variability in Ottobratica, Hamdi, FS-17, Gerboi, Arbequina, Persia, Nabali, Koroneiki and Earlik. Following pomological traits: fruit and stone weight (g), fruit and stone size (cm), fruit and stone shape index (length/width) and flesh to stone ratio were studied. Data for studied traits were collected in 2019 according to the International olive council descriptor. A significant genetic difference was noticed in the morphological characteristics of both fruit and stone. Different pomological characters were expressed by each cultivar. A wide range of variation was noticed in fruit weight (1.33-5.57g), stone weight (0.20-0.63g) and flesh/stone ratio (0.90-4.96). Based on their fruit shape, studied cultivars were classified into two groups i.e., ovoid and elongate. However, no significant difference was recorded for the stone shape, as all the studied cultivars had the same elongated stone shape. Concerning the fruit size, high fruit size (4-6g) was observed in FS-17, Hamdi, Earlik and Persia whereas Koroneiki, Nabali and Gerboi had the smallest ones (>2g). Based on our results, Earlik, Hamdi and FS-17 are suggested to be more appropriate for table olive production. Thus, an evaluation of genetic diversity through this study can help in the varietal development of olive for table and oil purposes.

Keywords: Flesh/stone ratio, Fruit weight, Olive, Pomological characterization, Stone weight

INTRODUCTION

Olive (*Olea europea*) belongs to the dicotyledonous family Oleaceae, and is considered one of the main growing oil crops in the world (Khadivi *et al*., 2022). It is cultivated on more than 12 million hectares worldwide showing wide variability in the form of 2600 different varieties for table and oil purposes conserved at the World Olive Germplasm Bank (Debbabi *et al*., 2022). Originally it is growing in the Mediterranean basin (representing 29% of the world supply) but now it is expanding to different areas of North America, South America, Oceania and South-Western Asia (Mousavi *et al*., 2019). Olive is currently growing commercially in 37 countries with Spain being top producer followed by Italy and Morocco. Other countries include Turkey, Greece, Egypt, Tunisia, Portugal etc (Atlasbig, 2019; Gulcemal *et al*., 2022). Olive is unique among other oil crops due to the presence of rich compounds such as phytosterols and polyphenols in its fruits and a well-balanced nutrient composition, including high levels of monounsaturated fatty acids in its oil (Cheng *et al*., 2017). Diverse climatic conditions ranging from warm humid, subtropical to cold temperate in different areas benefited olive farming in Pakistan (Ali et al., 2024). Approximately, 85 million wild olive trees are present in different provinces of a country (Jan *et al*., 2021). In Pakistan, olive cultivation is started both in arid and semi-arid areas but their adaptation rate is high in arid zone where a suitable climate is available for olive growth and development (Raza *et al*., 2021). About 45 million olive trees are commercially grown in these areas (Jan *et al*., 2021) with 1500 tons of olive oil and 830 tons of table olives are produced (Ali *et al*., 2024). Moreover, a number of olive plants of several varieties have been imported and planted in Pakistan (Iqbal *et al*., 2019). Punjab being the top province with 13 thousand acres under olive cultivation, while in Punjab, Pothowar region proves to be ideal region with 8615 acres under olive plantation (Jan *et al*., 2021). However, the commercialization of olive in Pakistan is still at its initial stage. To date very few studies have been performed to estimate the genetic variability of introduced olive cultivars through morphological characterization in Pakistan (Iqbal *et al*., 2019; Saqib *et al*. 2019; Sumrah *et al*., 2021). With the emergence of new olive growing areas along with an increase in the nutritional value of oil in the market and consumers, urge breeders to develop olive breeding programs (Dridi *et al*., 2019). Due to its cross pollination nature, a wide range of germplasm diversity exists. This genetic variation could serve as an important breeding material for the development of modern olive cultivars (Khadivi *et al*., 2022). Characterization of olive varieties' performance in a specific region is an important step that helps in studying varietal behavior and their usage as a table or oil purpose (Kartas *et al*., 2016). Furthermore, genetic characterization in olive helps to select outstanding cultivars while eliminating genepool that does not have the potential to the improvement of oil or table olive. While most olive breeding programs prioritize improving olive oil quality, few focus on enhancing fruit characteristics for table olive production (Ozdemir *et al*., 2016). Olive plants' performance is usually examined by agronomical descriptors and pomological traits studies. Pomological characterization of olive fruit not only aids in genetic improvement programs but also help in the selection of genotypes suitable for table, oil, or dual purpose (Kartas *et al*., 2016). Olive fruit consists of three parts, exocarp (skin), mesocarp (flesh): edible portion of olives where olive oil accumulation starts, and lignified endocarp which surrounds and protects seeds (Methamem *et al*., 2015). Variability among cultivars is easily detected by morphological analysis of fruit, endocarp size and shape (Blazakis *et al*., 2017). As genetic makeup of variety significantly impacts fruit growth and development. Moreover, the characterization of fruits in terms of fruit weight, pulp %, stone size, etc defines its usage. Generally, table olives have maximum fresh weight content with minimum oil content for easier preservation, while for oil purposes, a high oil percentage is favorable (Kartas *et al*., 2016). Therefore, morphological studies are considered as an efficient tool for characterization and discriminating olive cultivars (Blazakis et al., 2017). Thus keeping in view the importance of olives, this study aims at characterizing 9 cultivars of olive trees cultivated in the field area of BARI, Chakwal to estimate genetic variability based on pomological characteristics.

MATERIAL AND METHODOLOGY

Experimental site: The present experiment was conducted at the research area of Barani Agricultural Research Institute Chakwal in 2019. This area is located at 32º Latitude and 72º Longitude having 575m altitude. It is arid to semi-arid with annual rainfall up to 772 mm annual. The climate of the region is characterized as subtropical with an annual mean temperature of 22.3ºC (Sumrah *et al*., 2021; Hassan *et al*., 2022).

Plant Material*:* Nine exotic olive cultivars were selected for pomological characterization on the basis of their performance and yield. Cultivars selected were Ottobratica, Hamdi, FS-17, Gerboi, Arbequina, Persia, Nabali, Koroneiki and Earlik (Table 1). The studied olive trees were planted at 6 × 6m geometry on sandy loam soil having less than 1% organic matter with pH 8.1 and subjected to all common olive cultivation practices (Iqbal *et al*., 2019). A randomized complete block design was used with three replications per cultivar. The pomological characterization of olive cultivars was carried according to olive descriptor [International Olive Oil Council-IOOC (Barranco *et al*., 2000)].

Data Collection: After the pit hardening stage (90 days after flowering), the fruit was harvested by hand from each cultivar from all replicates. To record pomological data, 50 fruits were sampled from each replicate of each cultivar (150 fruits per cultivar). The studied pomological characters were fruit weight (g), stone weight (g), fruit size (cm), stone size (cm), fruit shape index (length/width), stone shape index (length/width) and flesh/stone ratio.

Fruit and stone length and width were measured through a vernier caliper while single fruit weight was measured through electronic balance. For stone weight, fruit was cut and stone were extracted, washed and weighed. The flesh/stone ratio was estimated by dividing flesh weight by stone weight.

To determine fruit and stone size and shape, they were classified into different classes based on weight and length/width ratio. For fruit shape, fruits were classified in to spherical (L/W< 1.25), ovoid (L/W = 1.25 – 1.45) and elongated (L/W > 1.45). Categories of stone shape were spherical (L/W < 1.4), ovoid (L/W = 1.4 to 1.8), elliptic (L/W = 1.8 - 2.2) and elongated (L/W > 2.2). Olive fruit size is divided into low (< 2 g), medium (2- 4 g), high (4 - 6 g) and very high (> 6 g) while for stone size, classes were low (<0.3 g), medium (0.3–0.45 g) and high (>0.45 g) (Methamem *et al*., 2015; Agripoulou *et al*., 2021).

Statistical analysis: Data collected for different traits were subjected to analysis of variance (ANOVA) through the statistical software Statistix 10.1 to ascertain differences among the means of various genotypes. Where differences among means was studied through the least significant difference (LSD) at 0.05% probability level (Steel *et al*., 1997).

RESULTS

Results of analysis of variance exhibited significant variation in the pomological traits of different olive cultivars. According to table 2, the maximum coefficient of variation (*cv*) was found mainly for stone parameters such as stone weight (45.38), stone index (28.64) and stone width (25.97) which suggests high variability for stone traits among olive cultivars. Whereas the minimum coefficient of variation observed in fruit index (12.54), fruit length (11.07) and fruit width (9.56) that showed low amount of variability in fruits of different olive cultivars.

For fruit related traits, statistical analysis indicated high genetic variability (Table 3). Means for fruit weight ranges from 1.33 g in Gerboi to 5.56 g in FS-17. Similarly, minimum fruit length (1.26 cm) and width (0.73 cm) were also observed in the variety Gerboi. Whereas, maximum fruit length was studied in Hamdi (2.73 cm) while highest fruit width was found in FS-17, Earlik (1.90 cm) and Hamdi (1.86) respectively. However for fruit shape index parameter, the Arbequina variety showed maximum value (1.89) and Koroneiki had minimum (1.25) fruit length/width ratio (Figure 1).

Table 1. Brief description of olive cultivars used in this experimental study

Cultivar	Origin	Usage	Size	Planting year
Ottobratica	Italy	Oil	Small to medium	1991
Hamdi	Palestine	Table	Medium	2004
FS-17	Italy	Table	Medium	2005
Gerboi	Italy	Dual	Small	2005
Arbequina	Spain	Table	Small to Medium	2004
Persia	Greece	Oil	Medium	2005
Nabali	Palestine	Dual	Small	2004
Koroneiki	Greece	Oil	Small	2012
Earlik	Israel	Table	Medium	2004

Table 2. Analysis of variance of different pomological traits of olive cultivars

SOV	Fruit length	Fruit width	Fruit weight	Stone length	Stone width	Stone weight	Flesh/stone ratio	Fruit index	Stone index
Genotypes	0.698	0.533	9.532	0.137	0.039	0.088	8.298	0.122	4.414
Reps	0.009	0.004	0.763	0.028	0.007	0.014	0.851	0.002	2.179
Error	0.05	0.018	0.46	0.018	0.009	0.042	0.530	0.036	1.355
CV (%)	11.07	9.56	20.79	10.45	25.97	45.38	25.77	12.54	28.64

Table 3. Variation in fruit traits among different olive cultivars

Olive variety	Fruit weight (g)	Fruit length (cm)	Fruit width (cm)	Fruit Shape Index	Flesh/stone Ratio
Ottobratica	2.30 c	2.06 cd	1.36 b	1.51 bcd	1.83 c
Hamdi	5.33 ab	2.73 a	1.86 a	1.47 bcd	4.80 ab
FS-17	5.56 a	2.57 ab	1.90 a	1.35 cd	4.96 a
Gerboi	1.33 c	1.26 f	0.73 c	1.72 ab	1.06 c
Arbequina	2.30 c	1.76 de	0.93 c	1.89 a	2.10 c
Persia	4.20 b	2.26 bc	1.46 b	1.54 bcd	3.60 b
Nabali	1.43 c	2.03 cd	1.23 b	1.66 abc	0.90 c
Koroneiki	1.80 c	1.63 ef	1.30 b	1.25 d	1.56 c
Earlik	5.23 ab	2.53 ab	1.90 a	1.36 cd	4.60 ab

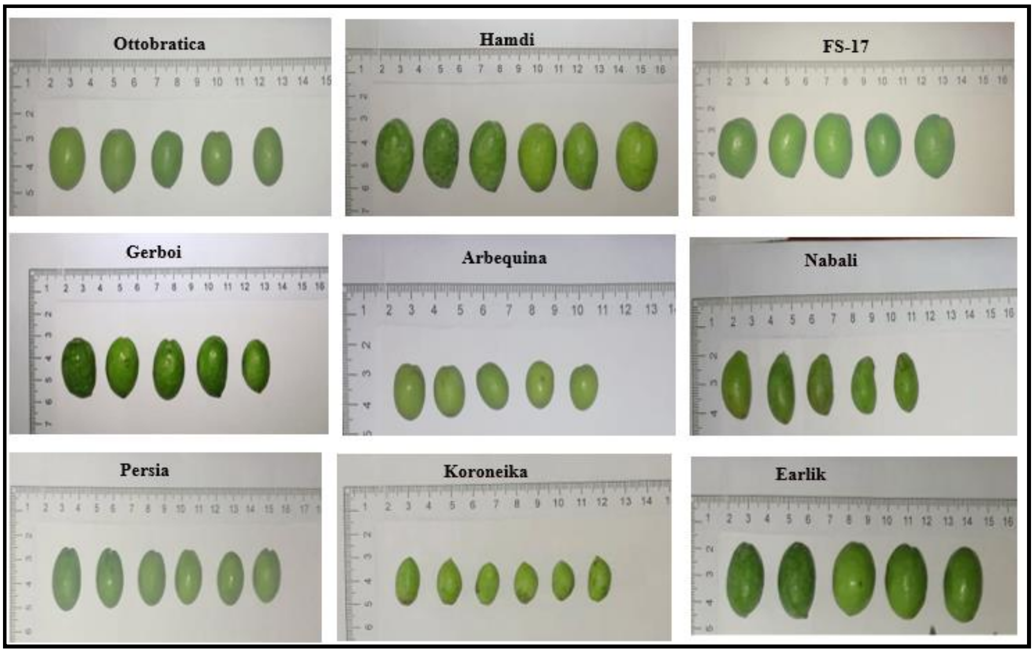

Figure 1. Variation among fruits of different studied cultivars

Analysis of variance showed that the differences among nine studied genotypes were highly significant (Table 4) for stone parameters. Earlik variety produced a stone of maximum weight (0.63 g) followed by FS-17 (0.60 g). While stone of light weight were observed in the Koroneiki variety (0.23 g). Stone length observation showed that Hamdi, Ottobratica and Earlik had larger stone of the same length (1.50 cm) whereas, Koroneiki had stone of minimum length (1.0 cm). For stone width, Hamdi, FS-17 and Earlik produced wider stone (0.5, 0.5 and 0.46 cm) but Gerboi had stone of minimum width (0.16 cm) respectively. Concerning the stone shape index, Gerboi and Arbequina had the highest value (5.98 and 4.62) while other cultivars were not significantly different with shape index ranges from 3.00 in Hamdi to 4.08 in Ottobratica. On the basis of fruit and stone weight, the difference among means for flesh/stone ratio revealed that highest flesh/stone ratios was found in FS-17 (4.96) followed by Hamdi (4.80) and Earlik (4.60), while the least flesh/stone ratio was found in Nabali (0.90) (Table 4).

Table 4. Variation in stone traits among different olive cultivars

Olive variety	Stone weight (g)	Stone length (cm)	Stone width (cm)	Stone Shape Index
Ottobratica	0.46 abc	1.50 a	0.36 ab	4.08 b
Hamdi	0.53 abc	1.50 a	0.50 a	3.00 b
FS-17	0.60 ab	1.43 ab	0.50 a	2.90 b
Gerboi	0.26 bc	1.00 c	0.16 c	5.98 a
Arbequina	0.20 c	1.23 bc	0.26 bc	4.61 ab
Persia	0.60 ab	1.46 ab	0.36 ab	3.99 b
Nabali	0.53 abc	1.46 ab	0.30 bc	4.89 ab
Koroneiki	0.23 c	1.00 c	0.30 bc	3.33 b
Earlik	0.63 a	1.50 a	0.46 a	3.21 b

Descriptive studies of olive fruit shape varied between cultivars and grouped into two form types i.e., ovoid and elongate. Koroneiki, Earlik and FS-17 were ovoid (L/W= 1.25-1.45) while Persia, Nabali, Arbequina, Gerboi, Hamdi and Ottobratica were elongate (L/W > 1.45). Based on fruit weight, studied cultivars were divided into 3 groups. i.e. in low weight (< 2g), Nabali, Koroneiki and Gerboi fall; for medium fruit weight (2-4g), Ottobratica and Arbequina came; and for high fruit weight (4-6g), three cultivars "Hamdi, FS-17, Persia and Earlik" were found in this category. However for stone shape; no difference in shape were observed as all cultivars had elongated stone shape (L/W: 1.8-2.2, > 2.2). But for stone size, two classes were observed; Low (< 0.3g): Gerboi, Arbequina and Koroneiki and for high stone size (> 0.45 g); Ottobratica, Hamdi, FS-17, Persia, Nabali and Earlik falls. While no cultivar comes in low and very high shape size class (Table 5).

Table 5. Classification of olive fruit and stone shape and size

Category	**Fruit shape**	**Stone shape**
Spherical	-	-
Ovoid	Earlik, Koroneiki, FS-17	-
Elongate	Ottobratica, Hamdi, Gerboi, Arbequina, Persia, Nabali	Earlik, Koroneiki, FS-17, Ottobratica, Hamdi, Gerboi, Arbequina, Persia, Nabali
	Fruit Size	**Stone Size**
Low	Nabali, Koroneiki, Gerboi	Gerboi, Arbequina, Koroneiki
Medium	Ottobratica, Arbequina	
High	Hamdi, FS-17, Persia, Earlik	Ottobratica, Hamdi, FS-17, Persia, Nabali, Earlik
Very high	-	-

DISCUSSION

Olive cultivars are usually characterized by morphological, pomological, and oil parameters and through molecular markers. But plant description through morphological traits is easy to examine variability as these traits are influenced by genotype, environment and their interaction (Brkljaca *et al*., 2018). Pomological characteristics of olive fruits are mainly influenced by soil conditions, climatic (rainfall and temperature), fertilizer, cultivar, location, elevation and ripening stage (Kong *et al*., 2020; Gulcemal *et al*., 2022).

Fruit weight parameters are used as an indicator to determine plant yield. It determines the productivity potential and decides its use for different value added products (Sumrah *et al*., 2021). In the present research, difference between fruit length, width among studied cultivars was may be due to growing site and moisture conditions. As potential water requirement of olive trees depends upon the soil and climate of the area and water availability at the end of winter season. While varieties with lowest fruit weight was may be due to a lack of irrigation water. Similarly, variations in fruit weight and size among olive varieties were also studied due to differences in the geographical site and hydrous conditions in Beni-Mellal region of Morocco (Farssi *et al*., 2019). Differences in single fruit weight among five olive varieties in China were attributed due to tree vigour, crop density, soil moisture, availability of nutrients and fruit to leaf ratio. As shaded fruits tend to develop at a slower rate with reduced size because light act as an important factor in fruit growth (Kong *et al*., 2020). Highest fruit weight (6.5g) of table variety "Ascolana" and minimum weight (1.0g) of the oil variety "Chemlali" were studied by Dridi *et al*. (2019). On the basis of fruit weight, germplasm planted in South of Tunisia had fruits divided into two categories, low (>2g) and average (2-6g) (Jaouadi *et al*., 2009). The Fruit shape index parameter determines olive usage as a table or oil purpose. Furthermore, these traits also play an important role in the trade of olive fruits (Acila *et al*., 2017). As in this study, highest fruit shape index of Arbequina variety makes it an ideal table variety.

The olive endocarp is the woody internal part of the fruit that encloses the seed. Usually, the term stone describes both endocarp and seed together. Morphological study of endocarp for cultivar identification is more suitable than fruit or other organs because it is less affected by the environment due to its woody nature and protection from the pulp limits its exposure to environmental conditions (Blazakis *et al*., 2017). Seed size is an important quality factor as it determines flesh to seed ratio, particularly for table olive (Gulcemal *et al*., 2022). Pit weight of table olive must be in the range of 0.5-0.8 g and for edible oil weight has to 0.3-0.5 g respectively (Tanilgan *et al*., 2007). In the studied cultivars, stone weight of Hamdi, FS-17, Persia and Nabali was higher than 0.5g, identifying as table varieties. Maximum endocarp weight were observed in Karbuncela variety growing in Croatia (Brkljaca *et al*., 2018). Under the agro-climatic conditions of Tunisia, Tounsi cultivar had a very high stone size as compared to Chemlali whose stone was of the smallest size (Methamam *et al*., 2015). In the present study, the elongate stone shape of all studied cultivars suggested little to no influence of environment on stone parameters. Adakalic and Lazovic, (2018) studied the olive endocarp of both old olive and Zutica (commercially grown cultivar) in Montenegro which was elliptical and had medium size, but the old olive endocarp is wider at the base.

Flesh to stone ratio is an important quality parameter and the cultivar with the highest fruit to stone ratio had more economic value (Acila *et al*., 2017). Large size with desirable shape, color and high stone to flesh ratio was considered an ideal characteristics for varieties to be used as table purposes (Ozdemir *et al*., 2018). High percentage of pulp ensures high commercial value for both table and oil production (Dridi *et al*., 2019). Criteria regarding the selection of fruit for table purpose are proper size and shape, high flesh/stone ratio, and texture with ease in releasing of seed. According to research, flesh to seed ratio must be at least 5 for new table olive cultivars (Ozdemir *et al*., 2020). According to IOOC, for table and dual purpose, fruit weight must be more than 2.43 g and pulp to pit ratio of more than 5 is considered suitable (Padula *et al*., 2008). Pulp to seed ratio is an important traits in olive breeding and it must be high for table olives (Gundogdu and Kaynas, 2016). Flesh to seed ratio mainly depends on genotype despite being based on fruit weight which is usually influenced by the environment (Padula *et al*., 2008). The high fruit weight and flesh to stone ratio of FS-17 Variety suggested that it can be used as dual purpose. Flesh to stone ratio in range of 4-8 were studied by Kartas *et al*. (2016) in olive cultivated varieties planted in Ouazzane area of Morocco. While evaluating candidate line and cultivated variety ratio in the range of 3.2-4.5 were observed by (Ozdemir *et al*., 2018).

CONCLUSIONS AND RECOMMENDATIONS

Genetic variability evaluation is the first and most important step in any breeding program. The present study is a primary approach for the characterization of olive cultivars. Through pomological characterization, FS-17, Hamdi and Earlik produced larger sized fruit and proved to be more appropriate for table olive production due to maximum fruit weight and flesh/stone ratio. However, along with morphological studies, it would be desirable to utilize biochemical methods and molecular markers for characterization purposes, to exploit the results of the present study in genetic improvement programs.

NOVELTY STATEMENT

Determination of genetic diversity among existing germplasm is the most important step in any breeding program. Thus in present research, estimation of variability through pomological characterization help breeders to select these studied cultivars as a parent in varietal developmental program to improve local production of table and edible oil that would eventually lead to lessen the import of olive. Furthermore, this research would also help farmers for the commercialization of these cultivars at larger scale.

CONFLICT OF INTEREST

The authors have declared no conflict of interest

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