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Assessment of phenological, carpometric and yield allied attributes of olive cultivars harvested at different maturity stages

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Abstract

The phenological, carpometric and yield characteristics of olive cultivars: Frontoio, Manzanilla, Ottobratica, Pendolino and Picual were evaluated at different harvesting stages (Lemon green, Semi-ripe and Ripe) during 2014 and 2015 under irrigation condition at Olive Model Farm Sangbhatti, situated in Mardan-Pakistan (Latitude: 34°16′21.32″N; Longitude: 72°18′06.33″ and Altitude: 375 m). Pendolino started early flower opening on 12th April, taken as baseline for phonological attributes and took more days (9.50) to fruit set, while less days (6.33), started from 18th April were noted for Ottobratica. The cultivars Manzanilla and Picual attained lemon green maturity after 193.50 (25th October) and 192 (22nd October) days respectively, while 202.17 (2nd November) and 201.33 (1st November) days were taken by these cultivars to reach semi ripe stage and 214.17 and 210 days to ripe stage of harvesting respectively. Frontoio, Ottobratica and Pendolino attained semi ripe stage after 180.17 (11th October), 184.50 (20th October) and 193 (22nd October) days respectively, while 188 (19th October), 195 (30th October) and 203.67 (2nd November) days were taken by these cultivars to attain ripe stage of harvesting after flower opening. The cultivar Manzanilla produced heavy fruits (4.34 g), however large sized fruits (4.48 cm^3) with more pulp: stone (4.94) were yielded by Picual. High fruit yield (35.81kg $tree^{-1}$) and more oil percentage (14.66%) were determined in the oil extracted from fruits of Frontoio. Yield and yield components enhanced from lemon green to semi-ripe and ripe stage of harvesting, also the percentage of oil increased with the ripening process of olive fruits. Olive cultivars Frontoio, Manzanilla and Picual are recommended for high yield and production of olive oil.

Key words: Evaluation, Harvesting stages, Olive cultivars, Oil content, Yield

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Introduction

Olive is gaining importance in many areas of the world (Fernandez & Moreno, 1999; Nuberg & Yunusa, 2003) due to economical, environmental and human health concerns. Olive fruits and oil have been studied for many years from an analytical point of view (Gutierrez et al., 1999; Ranalli et al., 1999; Caruso et al., 2000) for their potential health benefits (Visioli & Galli, 1998; Larsen et al., 1999). Different olive cultivars respond variously in yield and oil content (Tubeileh et al., 2008) and react according to inheritance for particular traits and agro-ecological conditions (Lavee & Wodner, 2004) but the influence of genotype is greater than the climate in terms of various traits (Lanteri et al., 2002). The genotype, environment and their interactions determines olive oil production and quality (Mailer, 2005; Ceci & Carelli, 2010) thus; a possible interaction between genotype and environment modifies olive oil composition in many regions (Mannina et al., 2001; Torres et al., 2009).

Oil concentration in olive fruit (principally in the fleshy mesocarp) is a direct consequence of the rate of oil synthesis and the duration of the oil accumulation period (Trentacoste et al., 2012) that determine the harvesting stage of different varieties. Genotypic differences in fruit growth and oil synthesis capacity have been identified (Lavee & Wodner, 2004; Trentacoste et al., 2010; Hammami et al., 2011) and also changes in skin and flesh colours occur during fruit ripening, that serve as visual indicators of changes in chemical composition of oil (Beltran et al., 2004). Olives are washed only if they have been harvested from the soil or have spray residues. The extra moisture can reduce extraction efficiency, because water and oil emulsions are formed. Oils made from washed olives are usually less desirable, with a reduction in bitterness and pungency and also have a less fruity flavour (Fernandez, 1998; Civantos, 1999).

Pakistan is spending huge foreign exchange on the import of edible oil; during 2011-12 the import was 2.3 million tonnes worth 2.2 billion dollars (Pakistan Bureau of Statistics, 2011-12), while the import of olive oil during 2011 was 1209 tons worth 3322000 $ US (Food and Agriculture Organization [FAO], 2011). To curtail the import bill of edible oil, olives could be the best option to plant on marginal lands without disturbing the existing cropping system. Plantation of new orchards with the promising cultivars, evaluated under local conditions will add to the value and being a sub-tropical plant olive can be grown successfully in the subtropical mountainous region of Khyber Pakhtunkhwa and Balochistan (Baloch, 1994). According to estimate around 80 million wild olives (*Olea cuspidata*) are grown in the merged districts of Khyber

Pakhtunkhwa, Balochistan and Potohar region of Punjab, which shows the adaptation of olive in this part of world (Bongi & Palliotti, 1994), hence various commercial olive cultivars like: Pendolino, Manzanilla and Frontoio etc. are under cultivation in Pakistan (Pakistan Oilseed Development Board, 2010).

The scientific information on olive cultivars, introduced in Pakistan is scarce and limited research studies on olive cultivars and harvesting stages have been conducted so far in this region. The potential of most of them is not fully investigated yet, therefore the augmentation of olive culture in the country is limited. Selection of promising, high yielding cultivars with standard oil production, adapted to the local conditions and their plantation on marginal lands without disturbing the existing cropping system of Pakistan will lead toward self-sufficiency in high value edible oil production. Our study represents an initial step towards characterizing some of the introduced olive cultivars present in the country to explore the potential of these cultivars. Also, to provide information to researchers, extension agents, planners and farmers about phonological characteristics, carpometric traits, yield and oil content of the studied cultivars.

Materials and Methods

The study was conducted during 2014 and 2015 under irrigation condition on ten years old, five olive cultivars (Frontoio, Manzanilla, Ottobratica, Pendolino and Picual) spaced at 6 x 6 m at Olive Model Farm Sangbhatti, situated in Mardan, Khyber Pakhtunkhwa-Pakistan (Altitude: 375 m; Latitude: 34°16′21.32″N; Longitude: 72°18′06.33″). The soil structure in the farm is silt loam with 0.67 % organic matter and 7.00 pH. The region has an average annual rainfall of around 600 mm, mainly occurs in July-August and the dry season lasts from May-June. Annual rainfall during the crop years was 550 and 630 mm respectively. Mean minimum temperature ranged from 2 °C in the coldest months (December-January) to 25 °C in the hottest months (June-July) while the mean maximum temperatures for the same months varied from 18 to 38 °C.

Ten years aged, three plants of similar size per treatment were selected, marked with paint and monitored to record the relevant data. The plants were subjected to routine cultural practices and ploughed the soil four times every year (after fruit harvest in autumn, in spring and twice in summer) using a cultivator. Well rotted FarmYard Manure @ 15 kg in winter and inorganic fertilizers: Di-ammonium Phosphate (DAP) @ 1.5 kg and 3 kg Urea (in 3 equal split doses; before the commencement of new growth and flowering, after one month of fruit set and after rains in monsoon) per tree were applied annually.

Phenological data were recorded, starting from the period of flower opening and taken as the base line for the remaining attributes of days to fruit set, days to lemon green, semi-ripe and ripe stages of harvesting. Three plants of each cultivar were harvested at each stage in each replication for yield and other attributes. The detailed procedure for data collection is given below.

A. Phenological data

Date of flowering

Date of first flower opening was recorded and treated as the base line for counting of days to fruit set, lemon green, semi-ripe and ripe stages of harvesting.

Days to fruit set

Number of days was counted for each treatment starting from the date of flowering to fruit set during the consecutive years and averaged for statistical analysis.

Days to lemon green stage

Days were counted from the base line upto the harvest at lemon green stage during both years of the trial and average was calculated and analyzed accordingly.

Days to semi-ripe stage

Days were counted from the base line upto semi-ripe stage of harvesting during both years of the trial and averaged for calculation and analysis accordingly.

Days to ripen stage

Days were counted from the base line upto the harvest at the ripe stage each year of the trial and average was calculated and analyzed statistically.

B. Carpometric and yield data

Fruit weight (g)

Sample of hundred fruits was collected randomly from each treatment and an average single fruit weight in grams was calculated by the formula

$$\text{Fruit weight (g)} = \frac{\text{Weight of the sample (g)}}{\text{Number of fruits in the sample}}$$

The two years average value of fruit weight harvested at three stages from five cultivars was analyzed statistically using two factorial ANOVA.

Pulp weight (g)

Sample of randomly selected hundred fruits in each treatment were de-pitted, pulp weight was determined and computed the pulp weight for single fruit by using formula

$$\text{Pulp weight (g)} = \frac{\text{Weight of the pulp (g)}}{\text{Number of de-pitted fruits in the sample}}$$

Data recorded during two crop years were averaged and put under analysis using software Statistics-8.1.

Stone weight (g)

The stones, de-pitted through a machine from the randomly selected hundred fruits in each treatment were weighed and calculated the weight of single stone by the formula

$$\text{Stone weight (g)} = \frac{\text{Weight of the stones (g)}}{\text{Number of stone in the sample}}$$

The two years data were averaged for statistical analysis.

Pulp: stone

The ratio between pulp and stone for all the treatments was calculated by the given formula and average value recorded during two consecutive crop-years was statistically analyzed for variation

$$\text{Pulp: stone} = \frac{\text{Pulp weight (g)}}{\text{Stone weight (g)}}$$

Fruit volume (cm^3)

Fruit volume in each treatment was worked out by the water displacement method using the graduated cylinder. Water was put in the graduated cylinder and initial volume was noted then ten fruits from each treatment were put in the cylinder and final volume was recorded. Volume of ten fruits was determined by subtracting the initial volume from the final and volume of single fruit was calculated by the formula

$$\text{Fruit volume (cc)} = \frac{\text{Volume of the sample (cc)}}{\text{Number of fruits in the sample}}$$

(1 ml of water =1 cm^3 or 1cc at 20 °C)

Average value was calculated for the crop years 2014 and 2015 and analyzed statistically.

Yield tree^{-1} (kg)

Total fruits harvested for each treatment were weighed and average yield tree^{-1} was calculated for each year and analyzed the average value of both years.

Oil content (%)

Fruits for each treatment were harvested and oil from the randomly taken sample of ten kilogram was extracted within eight hours by the oil extraction mill having crushing capacity of 50 kg fruits per hour, installed at Agricultural Research Institute (ARI) Tarnab, Peshawar. The percentage of oil content was determined by the given formula and two years data were averaged and analyzed.

$$\text{Oil content (\%)} = \frac{\text{Oil extracted (liters)}}{\text{Weight (Kg) of fruits processed}} \times 100$$

Statistical Procedure

The experiments were carried out according to Randomized Complete Block Design (RCBD), the two years average phenological data was analysed by one way analysis, while yield and yield components data were analysed according to factorial analysis using Statistix-8.1 software. If the data were found significant, these were subjected to the Least Significant Difference Test (LSD) at $P \leq 0.05$, for mean comparison (Steel *et al.*, 1997).

Results and Discussion

Phenological stages

Dates of first flower opening were recorded for each cultivar during two crop years (2014 and 2015) and treated as base line for counting the days between flowering and fruit set, lemon green, semi-ripe and ripe stages of harvesting. According to statistical data, the days between flowering and fruit set, lemon green, semi-ripe and ripe stages of harvesting were significantly different ($P \leq 0.05$) for olive cultivars. The first flower opening in Pendolino and Picual was observed on 12th and 13th April respectively. Frontoio and Manzanilla both opened their flowers on April 14, while the first flower opening in Ottobratica was noted on 18th April. More number of days to fruit set (9.50) were taken by cultivar Pendolino, followed by number of days to fruit set (8.00) recorded in cultivar Frontoio, while a smaller number of days to fruit set (6.33) was observed in cultivar Ottobratica which was statistically similar with the number of days to fruit set (6.67 and 6.83) taken by cultivars Manzanilla and Picual respectively. The difference among the mean values for fruit set in Ottobratica, Manzanilla and Picual cultivars were non-significant, while these were significantly different from Frontoio and Pendolino (Table 1). The fruits of cultivar Frontoio took less days (163.83, 180.17 and 188.00) to reach the lemon green, semi-ripe and ripe stages of harvesting respectively, while more days (193.50, 202.17 and 214.17) were taken by fruits of Manzanilla for harvesting at lemon green, semi-ripe and ripe stages. Toplu et al. (2009) reported almost similar results and stated that Manzanilla took more days (201) from full flowering to black maturity in Hatay province of Turkey. The mean values of days to the lemon green stage of harvesting for cultivars Frontoio, Ottobratica and Pendolino were statistically similar, while these were significantly different from the values of Picual and Manzanilla. The mean value for days to semi-ripe and ripe stages of cultivar Frontoio was significantly different from the rest of the cultivars. Fruit maturity and harvesting period at particular agro-climatic conditions determine the working period for processing the olive fruits. The harvest period can be altered by introducing olive cultivars having sequential harvesting stages. This ensures the quality of the product and also curtails the labour cost of harvest over short time periods. The results of the present study provided a database for the planners and growers about five cultivars being introduced in the country. The findings of present study are almost in agreement with the findings of Ulger et al. (2000), who reported 7-11 days flowering duration in olives (from flower opening to fruit set) in Antalya.

Table 1 Date of 1st flowering, days to fruit set, lemon green, semi-ripe and rip stages of harvesting of olive cultivars

Olive cultivars	Days to date of 1st flowering				
		Fruit set	Lemon Green	Semi Ripe	Ripe
Frontoio	April 14	8.00b	163.83b	180.17d	188.00e
Manzanilla	April 14	6.67c	193.50a	202.17a	214.17a
Ottobratica	April 18	6.33c	167.83b	184.50c	195.00d
Pendolino	April 12	9.50a	167.67b	193.00b	203.67c
Picual	April 13	6.83c	192.00a	201.33a	210.33b
LSD (α = 0.05)		0.6875	7.6588	2.6010	2.3504

Carpometric and yield data

Fruit weight (g)

Statistical analysis of the data reveals that cultivars, harvesting stages and their interaction have significantly affected ($P \leq 0.05$) the fruit weight in olive. The mean data illustrated that more fruit weight (4.34 g) was noted for the fruits of cultivar Manzanilla. The mean of which significantly varies from rest of the cultivars, followed by fruit weight (3.75 g) attained by fruits of cultivar Picual, while less fruit weight (1.92 g) noted in the fruits of Ottobratica. Fruit weight increased in the ascending order as the cultivars approached ripening and initiated from 2.50 g at lemon green, attained 2.90 g at semi-ripe and 3.22 g at the ripe stage of harvest (Table 2). The interaction between cultivars and harvesting stages indicated that heavy fruit weight was attained by the fruit of Manzanilla, harvested at the ripe stage, while less fruit weight was recorded for fruits of Ottobratica, harvested at lemon green stage (Fig. 1). The fruit weight is a trait linked to the genotype of variety and influenced by the annual environmental as well as plant management (Mahhou et al., 2012) while, an increasing trend in fruit weight is observed with ripening of the fruits (Atouati, 1991; Idrissi, 1994; Lachir & Sidi Baba, 1994; El Cadi & El Jamai, 1998; Faqih & Hmama, 1999). The findings of present investigations accord with the values for fresh fruit weight of different olive cultivars cited by Tubeileh et al. (2004).

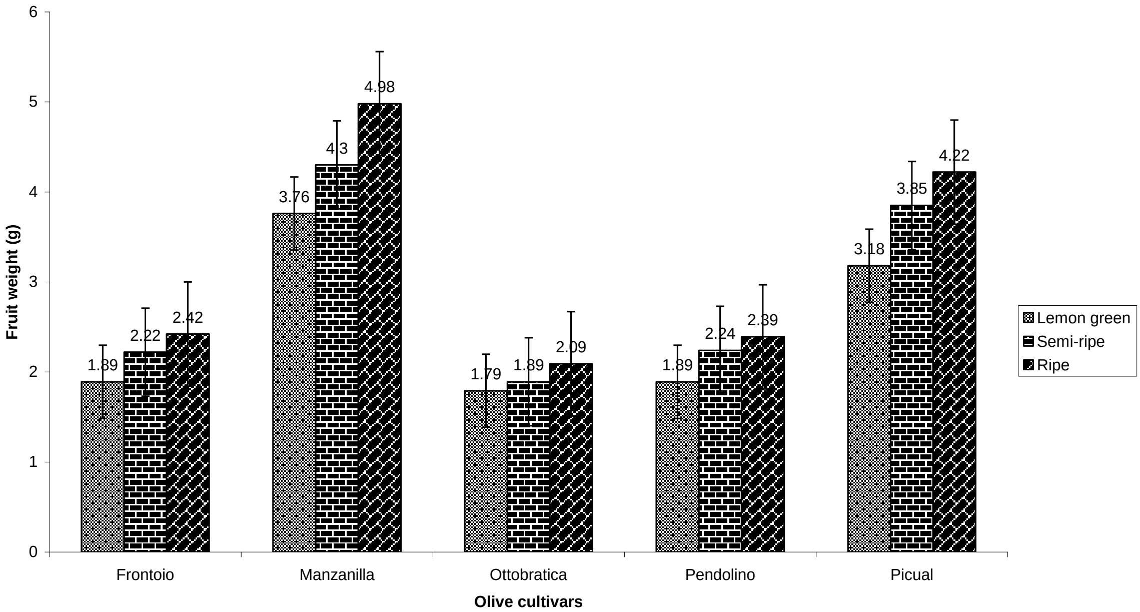

Fig. 1 Fruit weight (g) of olive cultivars as affected by harvesting stages

Pulp weight (g)

The ANOVA for the pulp weight revealed that there were significant variations among cultivars, harvesting stages as well as their interaction. The data indicated that maximum pulp weight (3.42 g) was recorded in fruits of cultivar Manzanilla, followed by 2.97 g pulp weight attained by fruits of Picual. The difference in average pulp weight of both the cultivars was statistically significant from each other and from the rest of cultivars. The less pulp weight (1.33 g) was noted in fruits of cultivar Ottobratica. The pulp weight followed an increasing trend with the maturity of fruits. The less pulp weight (1.82 g) was recorded for the fruits harvested at lemon green stage, while 2.16 g pulp weight was attained by fruits harvested at semi-ripe stage and the maximum fruit pulp weight (2.51 g) was noted in the fruits harvested at ripe stage (Table 2). In the interaction heavy pulp weight was produced by the fruit of Manzanilla, harvested at ripe stage, while light pulp weight was recorded for the fruits of cultivar Ottobratica, harvested at lemon green stage (Fig. 2). Pulp weight is a trait linked to the genetics of variety, environment and crop management conditions (Mahhou et al., 2012). The mesocarp grows more than the endocarp (Rosati et al., 2012), probably due to its longer growth period, up to fruit maturity (Hammami et al., 2011) and the differences across cultivars are mostly due to cell number, while cell size tends to be similar (Rapoport et al., 2004), despite the fact that fruit growth from the ovary to the mature fruit is mainly due to cell expansion than cell division (Hammami et al., 2011), hence different cultivars showed diverse response to this trait in the present study.

Table 2 Fruit, pulp, stone weight and pulp: stone of olive cultivars as affected by harvesting stages

Olive cultivars	Parameters			
	Fruit weight (g)	Pulp weight (g)	Stone weight (g)	Pulp: stone
Frontoio	2.18 c	1.54c	0.57c	2.69d
Manzanilla	4.34 a	3.42a	0.76a	4.49b
Ottobratica	1.92 d	1.33d	0.41d	3.25c
Pendolino	2.17 c	1.54c	0.58bc	2.64d
Picual	3.75 b	2.97b	0.60b	4.94a
LSD (α = 0.05)	0.0485	0.0271	0.0190	0.1261
Harvesting stages (S)				
Lemon green	2.50c	1.82c	0.55c	3.24c
Semi-ripe	2.90b	2.16b	0.58b	3.63b
Ripe	3.22a	2.51a	0.62a	3.93a
LSD (α = 0.05)	0.0376	0.0210	0.0147	0.0977
Interaction between olive cultivars and harvesting stages (Cv× S)				
Significance levels	* (Fig. 1)	*(Fig. 2)	NS	*(Fig. 3)

* = Significant; NS = Non-significant

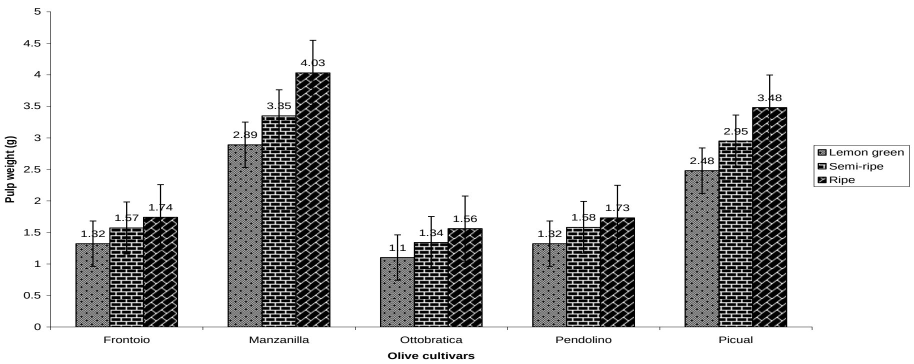

Fig. 2 Pulp weight (g) of olive cultivars as affected by harvesting stages

Stone weight (g)

The statistical differences of stone weight among the cultivars and harvesting stages at P ≤ 0.05 were significant but had non-significant interaction effects. The fruits of olive cultivar Manzanilla attained more stone weight (0.76 g), followed by stone weight (0.60 g) recorded for fruits of cultivar Picual; the means of which were significantly different from each other as well as from the rest of cultivars. The lighter stones with weight of 0.41 g were produced by Ottobratica. The stone weight increased as the maturity proceeded and maximum stone weight (0.62 g) was recorded in fruits harvested at ripe stage, followed by stone weight (0.58 g) noted in fruits, harvested at Semi-ripe while less stone weight (0.55 g) was observed in fruits harvested at Lemon green stage (Table 2). The stone weight is linked to the genotype characteristics and also to the environment and climatic conditions (Mahhou et al., 2012). Variation in pulp and pit weight was noted under various environmental conditions in different olive cultivars (Tubeileh et al., 2004) and the response of different olive cultivars to this trait can be linked with developmental processes that occur at different phases of maturity.

Pulp: stone

Significant differences (P ≤ 0.05) were found among the cultivars, harvesting stages and their interaction for pulp: stone in terms of weight. The highest pulp: stone (4.94) was observed in fruits of cultivar Picual, followed by pulp: stone ratio (4.49) noted in fruits of Manzanilla while the lowest ratio (2.64) was recorded in fruits of Pendolino. The means of all the cultivars were statistically different from each other. As the olive fruits proceeded to maturity, the values of pulp: stone in terms of weight increased. The olive fruits harvested at the lemon green stage generated low ratio (3.24) between pulp and stone, while the fruits harvested at semi-ripe stage yielded 3.63 pulps: stone and the high ratio (3.93) was recorded for fruits harvested at ripe stage (Table 2). The interaction between cultivars and harvesting stages illustrated (Fig. 3) that the highest value of pulp: stone was recorded for the fruits of Picual harvested at the ripe stage while low value was noted when fruits of Pendolino were harvested at the lemon green stage. Cell growth patterns differ among tissues (Rosati et al., 2011) and genotype, the size differs greatly among tissues with bigger but fewer cells in the endocarp compared to the mesocarp, however the mesocarp grows much more than the endocarp (Rosati et al., 2012), probably due to its longer growth period and greater cell number of small size (Rosati et al., 2012). The olive trees produce fruits according to its potential, the genetic component (cultivar differences) affecting fruit size in terms of mesocarp and endocarp, may be explained with the competition theory, based on the related differences in ovary size (which correlates with fruit size), implying different energetic costs for the development of one fruit. Though negligible studies have evaluated the carpometric, phenological and productive attributes of olive varieties introduced in this region, however pulp: stone of Manzanilla and Picual falls in the range (3.5 ± 0.3 to 5.9 ± 1.7) reported by Abdul-Hamid et al. (2007), also findings of the present study revealed the same pattern of increase in pulp to stone ratio as reported by Mahhou et al. (2012) when they harvested olive fruits at different intervals.

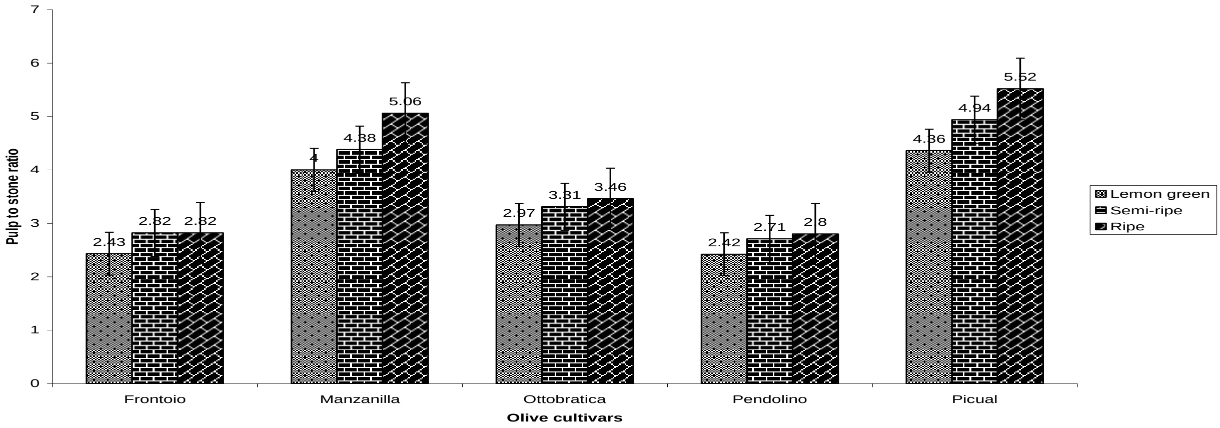

Fig. 3 Pulp: stone by weight of olive cultivars as affected by harvesting stages

Fruit volume (cm^3)

The statistical data showed that fruit volume was significantly affected by the olive cultivars, harvesting stages and the interaction of cultivars × harvesting stages at P ≤ 0.05. The cultivars varied significantly in terms of fruit volume of olive. The maximum fruit volume (4.48 cm^3) was attained by the fruits of cultivar Picual, followed by fruit volume (4.27 cm^3) noted in the fruits of Manzanilla, while less fruit volume (1.74 cm^3) was recorded in fruits of Ottobratica. The fruit volume increased with maturity of the olive fruits starting from 2.72 cm^3 at lemon green, 3.01 cm^3 at semi-ripe and 3.05 cm^3 at the ripe stage of harvesting (Table 3). The interaction between cultivars and harvesting stages indicated that large sized fruits were produced by the cultivar Picual harvested at the ripe stage, while smaller fruits were yielded by Ottobratica harvested at the lemon green stage (Fig. 4). Olive cultivars have different rates of fruit development which is related to the cell number (Rapoport et al., 2004). The fruit size is determined by the interaction of the environmental factors with the genetically determined growth potential of the fruits of particular genotype and photosynthates availability which depends on the source-sink balance (Rosati et al., 2009), also the initial size and growth potential of each ovarian tissue in olive could be a factor in its growth as part of the fruit (Rapoport & Martins, 2006). However, the volume of the studied cultivars did not match the findings of Patumi et al. (1999), who reported fruit volume 4.6 to 9.7 cm^3 of olive cultivars studied under irrigation conditions in Southern Italy.

Table 3 Fruit volume (cm^3), yield tree^{-1} (kg) and oil contents (%) of olive cultivars as affected by harvesting stages

Olive cultivars	Parameters		
	Fruit volume (cm^3)	Yield tree^{-1} (Kg)	Oil content (%)
Frontoio	2.19c	35.81a	14.66a
Manzanilla	4.27b	35.42a	11.93b
Ottobratica	1.74e	13.92d	7.31d
Pendolino	1.96d	19.06c	9.44c
Picual	4.48a	25.47b	11.38b
LSD (α = 0.05)	0.0674	1.9968	0.6841
Harvesting stages (S)			
Lemon green	2.72b	17.58c	8.23c
Semi-ripe	3.01a	27.81b	11.76b
Ripe	3.05a	32.41a	12.85a
LSD (α = 0.05)	0.0522	1.5467	0.5299
Interaction between olive cultivars and harvesting stages (Cv × S)			
Significance levels	* (Fig. 3.4)	*(Fig. 3.5)	*(Fig. 3.6)

* = Significant

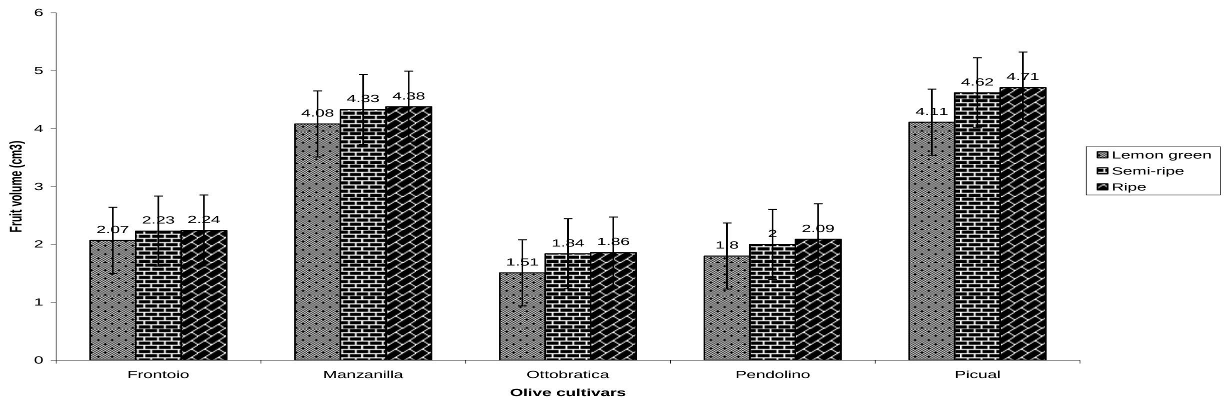

Fig. 4 Fruit volume (cm^3) of olive cultivars as affected by harvesting stages

Yield tree^{-1} (kg)

Significant differences were observed in yield tree^{-1} (kg) among olive cultivars, harvesting stages and the interaction of cultivars and harvesting stages. The maximum yield tree^{-1} (35.81 kg) was obtained by plants of cultivar Frontoio, followed by yield tree^{-1} (35.42 kg) produced by cultivar Manzanilla, however the variations among their means were non-significant at P ≤ 0.05. The minimum yield tree^{-1} (13.92 kg) was produced by plants of Ottobratica. The cultivars produced more yield when harvested late and maximum yield tree^{-1} (32.41 kg) was achieved when fruits were harvested at ripe stage followed by 27.81 kg yield tree^{-1} at semi-ripe and 17.58 kg at lemon green stages of harvesting (Table 3). In the interaction maximum yield tree^{-1} was produced by plants of Manzanilla, harvested at ripe stage, while minimum yield tree^{-1} was attained by Ottobratica when fruits were harvested at lemon green stage (Fig. 5). Yield is associated mainly with cultivar potentials (Padula et al., 2008), differentiation of flower buds, floral formation, fruit set and growth (Webster, 2002). Higher fruit yield, produced by Frontoio may be the genetic potential of the cultivar and conducive environment. Toplu et al. (2009) reported the same trend of yield enhancement; the fruit yield gradually increased towards ripening and the cumulative yields of 25.0 kg tree^{-1} was noted in cultivar Manzanilla; however, the yield of Manzanilla recorded in the present study is more than reported by the author.

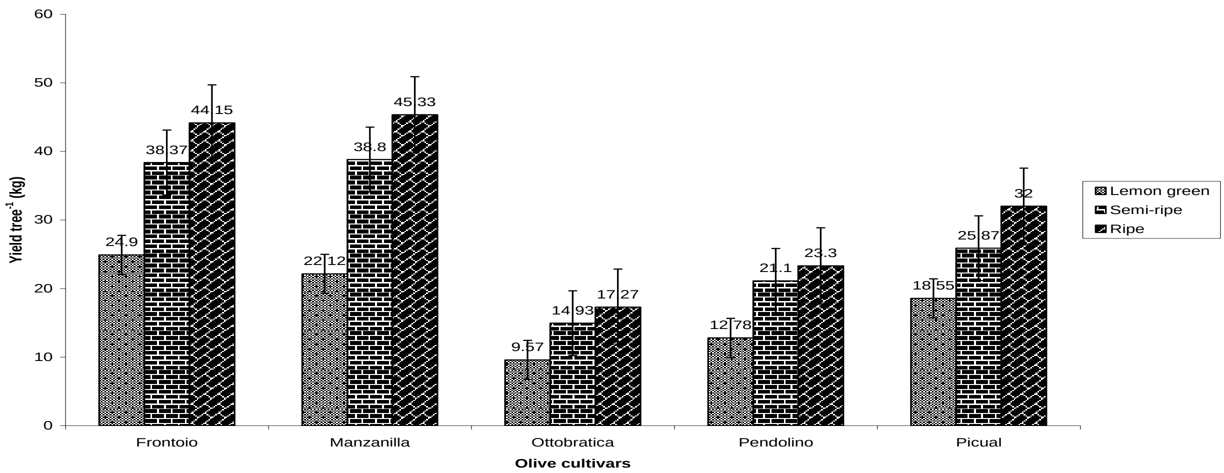

Fig. 5 Fruit yield tree^{-1} (kg) of olive cultivars as affected by harvesting stages

Oil content (%)

The data indicated significant variations in oil content among different olive cultivars, harvesting stages and the interaction of cultivars × harvesting stages at P ≤ 0.05. The maximum oil content (14.66%) was extracted from the fruits of cultivar Frontoio, the mean of which is significantly different from the percent oil contents obtained from the fruits of rest of the cultivars, followed by the oil contents percentage (11.93%, 11.38%) obtained from the fruits of cultivars Manzanilla and Picual respectively, and are statistically at par with each other. However less oil content (7.31%) was extracted from the fruits of Ottobratica. The percentage of oil increased with the ripening process of olive cultivars and more oil content (12.85%) was extracted when fruits were harvested and crushed at ripe stage followed by 11.76% oil content achieved from the fruits harvested at semi-ripe stage for processing, while less oil content (8.23%) was extracted when fruits were harvested at lemon green stage of harvesting (Table 3). More oil was extracted from fruits of cultivar Frontoio when harvested at the ripe stage, while a low percentage of oil was obtained from fruits of Ottobratica, harvested at lemon green stage (Fig. 6). The intensity of oil formation is a genetic trait among the olive cultivars, but also depends on soil and climatic conditions and crop management (Civantos, 1999). The biosynthesis of oil go on rapidly at the green stage of olive and increase until they turn completely black (ripe), after which oil content stabilises (Suarez, 1984) and even records a small decrease at advanced stages of maturity (Lachir & Baba, 1994; El Cadi & Jamai, 1998). The decline in oil content could be attributed not only to the accumulation of dry matter in olives at an advanced stage of ripening but also because of endogenous lipases (active at the black stage) which hydrolyze the triglycerides and fatty acids (Harrar, 2007).

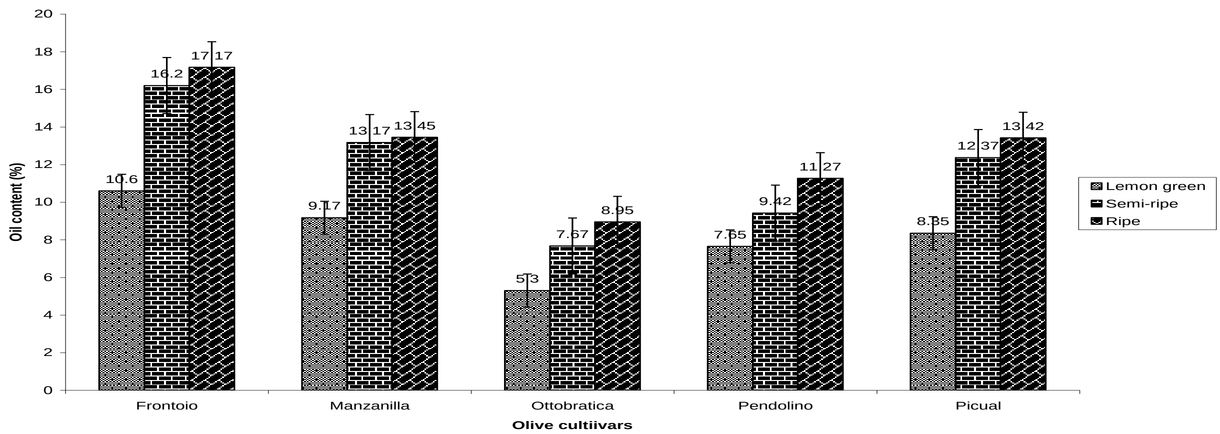

Fig. 6 Oil content (%) of olive cultivars as affected by harvesting stages

Conclusion and recommendations

Among the studied cultivars; Frontoio seems to be promising under the local conditions of Sangbhatti, Mardan-Pakistan and merits more attention for early ripening, high productivity and production of oil. The cultivar Manzanilla is categorized for high productivity (almost at par with Frontoio) and good oil recovery. The oil content from the fruits of Picual was statistically at par with Manzanilla, also large sized fruits having more pulp: stone were yielded by Picual. The performance of Ottobratica in terms of yield and oil recovery was not satisfactory. The olive cultivar Frontoio is recommended for early ripening, high productive and oil production potential under the local agro-climatic conditions of Sangbhatti, Mardan and other similar environments. Manzanilla and Picual both are recommended for cultivation due to their large sized fruits, more pulp: stone, optimum yield and good oil recovery. Pendolino is also recommended that marginally qualifies for the studied attributes, while Ottobratica is recommended to be tested in other ecologies. Oil content increased with the ripening process of olive fruits but further investigation is needed to find out the appropriate stage of harvesting that determines the equilibrium among olive oil recovery and quality.

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