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RESEARCH ARTICLE

Influence of geographical locations on yield, oil productivity and fatty acid profiling in four olive cultivars

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ABSTRACT

Olives and its oil are considered an imperative element of diet due to their excellent nutritional quality. Geographical factors (i.e., geology, slope, elevation and temperature) and genetic variability in different olive cultivars influence plant growth, yield, oil and profiling of fatty acids. The prime objective of this investigation was to demonstrate the prodigious consequences of high temperature on the growth, production, and fatty acid composition of four olive cultivars (Coratina, Frantoio, Ottobratica and Leccino) at three different geographical locations (BARI, IOF, HRS) with the range of 460-751 m altitude during the year 2017 and 2018. The study has been carried out to investigate different parameters such as climatic conditions (rainfall and temperature), phenological attribute and yield traits (fruit set, fruit weight, yield, and oil content), and oil quality and profiling of fatty acids (free fatty acid contents, peroxide, palmitic acid, palmitoleic acid, oleic acid, linoleic acid, and linolenic acid). The results indicated a positive correlation of yield with rainfall and negative with the temperature was observed among olive cultivars. The results showed higher rainfall (1189 mm) and temperature (37.51 °C) at location-1 and lower rainfall (525 mm) and temperature (36.05 °C) at location-3. Coratina and Frantoio depicted significantly higher fruit set and yield in warmer climatic regions (Location-1 and Location-2) while Leccino and Ottobratica showed better results in the cooler region. Higher oil content was found in Frantoio and Coratina at location-3 among other locations and other cultivars. Overall, the lowest free fatty acid value was exhibited in Coratina and the highest in Ottobratica at all locations in both seasons. The contents of peroxide were observed higher in Leccino and lower in Coratina at all locations. The results revealed less variation among fatty acid composition in cultivars and seasons, however, palmitic acid, palmitoleic acid and oleic acid contents were found higher at location-2, linoleic acid at location-3, and linolenic acid at location-2 in all four olive cultivars. Custer analysis revealed two main groups and group-I contained two subgroups (A and B) while group-II contained three subgroups (C, D and E). In principal component analysis (PCA), PC1 axis had Leccino-L3, Leccino-L1, Frantoio-L1, Ottobratica-L1, Coratina-L1, and Leccino-L3 and explained 91.99% of the total variation. Therefore, geographic location influence growth, yield and olive oil quality attributes.

Keywords: Climatic conditions; Acid value; High temperature; Free fatty acids; Oleic acid; Olive cultivars; Pothwar-Pakistan

INTRODUCTION

Olive is a drought-tolerant plant but as a sessile organism, it must subsist with a variety of abiotic or biotic environmental stresses (Ahmed 2019). The temperature fluctuation is a critical factor which naturally occurs during the vegetative and reproductive growth phase (Sung et al., 2003). The visual symptoms due to high temperature at initial stages may be observed in the form of leaf abscission (Ismail and Hall, 1999), sunburn and stunted growth (Vollenweider et al., 2005), and reduction in oil content and quality at fruit maturation stage (Wilhelm and Günthardt-Goerg, 1999; Maestri et al., 2002, Taha and Ahmed 2016). The sensitivity of the reproductive phase is more vernally to high temperature and causes yield reduction (Fahad et al., 2017). The accumulation of oil in olive fruits begins late

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summer and at the ripening stage slow down which is a genotypic character and highly associated with climatic conditions during olive fruit development and maturation (Conde et al., 2009; Gucci et al., 2009, Ahmed et al., 2019).

Olive old demand has been increased considerably due to its extraordinary health benefits having anti-inflammatory, anticancer, and potential therapeutic characteristics (Tufarelli et al., 2017; Servili et al., 2009; Parkinson and Keast, 2014). Monounsaturated oleic acid is highly abundant (about 80%) in olive oil which plays an imperative role in reducing cardiovascular diseases. Moreover, oil contained considerable amount of saturated fatty acids and polyunsaturated fatty acids (Ahmad et al., 2017; Taha and Ahmed 2016; Visioli et al., 2005). High level of antioxidant capacity in olive oil reported plentiful anticancer properties (Waterman and Lockwood, 2007), pharmacological properties (El Bohi et al., 2020) and especially have the potential impact in reducing breast cancer disease (Owen et al., 2000; Visioli and Galli, 2002).

Contamination may occur in food items by high-temperature treatments through the conversion of hazardous metabolites under enzymes action (Hoie et al., 2018). Therefore, olive oil content and quality have a prime importance for olive cultivars (Kiritsakis et al., 1998). Many other factors like cultivars, climatic conditions, soil, harvesting time, and processing affect the oil characteristics (Xylia et al., 2022). Moreover, oil quantity and quality in the fruit is also dependent on fruit maturity, moisture contents, crop load and varies from year to year (Ahmed et al., 2019; Al-Juhaimi et al., 2017; Lanteri et al., 2002).

Numerous scientists noticed considerable variations in physical parameters and phenolic compounds compositions of EVOO due to the impact of different geographic (Vinha et al., 2005; Dagdelen et al., 2013; Sousa et al., 2015; Gouvinhas et al., 2017). Touati et al. (2022) reported the oil quality and constituents were found notably affected due to geographical location and cultivar diversity. Chemlal and Sigoise planted in Eloued region exhibited significantly higher tocopherol and phenolic contents. While higher monounsaturated fatty acid contents were observed in olive cultivars from Eloued and Setif region. Moreover, Sigoise cultivar showed higher unsaturated fatty acid content in Batna region while revealed higher content of polyunsaturated fatty acid from the Eloued region. Cetinkaya et al. (2017) documented the influence of geographical factors on oil yield and fatty acid profiling of olive. The results revealed that change in fatty acid content and olive oil yield was weakly correlated with slope of region while strongly correlated with elevation of the area.

The International Olive Council (IOC) has established various categories to identify the oil quality with respect to acidity level and chemical properties. The olive oil having less than 0.8% acidity and free from organoleptic defects classified as extra virgin olive oil (EVOO). The organoleptic quality of EVOO is ascribed to presence of volatile compounds i.e., aldehyde, ketones, ester and alcohol. These qualities are extremely valued by customers (Gomez-Romero et al., 2012). The sensory traits and oil quality of olive are extensively associated to its varietal diversity and geographical location (Perri et al., 2012).

The growth, yield and oil productivity of olive cultivars may fluctuate from location to location. The most crucial features for the selection of any genotype in a certain area, except the Mediterranean region, are physiological, morphological, phenological, and yield. Therefore, it was imperative to evaluate different exotic olive cultivars adapted in Pakistan for the production of oil. Moreover, the biochemical qualities of EVOO from these varieties were also estimated for varietal interaction with respect to location and year of production in high-temperature zones.

Olive is considered to be one of the most important emerging horticultural crops in Pakistan. Olive cultivation is rapidly increasing in the region due to socio-economic importance (Iqbal et al., 2019). It is being planted in semi-arid environmental conditions of Punjab where the temperature often rises up to 42 °C in summer. We have also studied the behavior of olive cultivars towards summer temperature. Therefore, the present investigation was designed to explore the impact of geographical locations and/or cultivars on the fruit yield, quantity, and quality of oil as well as fatty acid composition.

MATERIALS AND METHODS

Collection of material

Field study on yield, yield associated factors, and olive oil quality attributes was performed in two successive seasons 2017 and 2018 on four olive cultivars (Coratina, Frantoio, Ottobratica, Leccino) having the same age (8-10 years). Twelve plants of each variety that were similar in height, age, and canopy were selected for our experiment. All selected cultivars were planted at a distance of 20 f x 20 f and properly pruned to a central open shape. Appropriate cultural practices i.e., fertilization, irrigation and hoeing were applied to all selected olive cultivars. Three locations were selected such as Barani Agriculture Research Institute (BARI) location -1 (320 92’82 N & 720 7201 E, altitude 575 m), Izhar Olive Farm (IOF) location-2 (320. 46’330 N and 72. 42 030 E, altitude 460 m) and Horticulture Research Station (HRS), Nowshehra location-3, altitude 751 m from agroecological conditions of Pothwar (Fig. 1). These sites were considered more suitable for the cultivation of olives in this region. The climate of all three locations was arid to semi-arid and the physicochemical soil characters for these locations are mentioned in Table 1. The weather information was gathered with the aid of weather station (HOBO,) installed at location-1 and location-3 and weather station (Sensovant, Spain) mounted at location-2.

Varietal characterization regarding phenology, productivity, oil quantity and quality of four olive varieties was addressed under the effect of different temperature and rainfall regimes. Fruit yield per plant was measured because it directly influences the fruit weight as well as oil contents following the randomization protocols.

Measurements of oil content (%)

Oil content from the olive cultivars was assessed by following the official method PN-EN ISO 659:1999 (1999) and PN-73/R-66164 (1973) and expressed in percentage.

Determination of acid value (%) and Peroxide value (meq/kg)

The free fatty acids are described in terms of oleic acid because it is most abundant (55-83%) fatty acid present in olive oil (Rodrigues et al., 2016). The acid value was estimated according to the manual titration method (Saude et al., 2017). The protocol demonstrated by Metcalfe et al. (1966) was employed to determine the peroxide value.

Estimation of fatty acid composition

The oil was extracted with a laboratory mill (Italian continuous olive processing plant "*Pieralisi Fattoria)*. The biochemical quality parameters were evaluated by following the official and analytical chemistry procedures. Trans-esterification with a cold potassium hydroxide methanolic solution was used to transform fatty acids into methyl esters in accordance with International Olive Council (COI/T.20/Doc. 24) and European Union (EU Regulation- EN 1991R2568) procedures. Gas chromatographic analysis was used to determine each fatty acid component. 015).

Statistical analysis

The current study was designed according to randomized complete block design (RCBD) with factorial arrangement. The least significant difference test at 0.05 possibility was employed to assess significant differences between four olive cultivars. All statistical analysis were performed using XLSTAT, 2014; v.5.03 software.

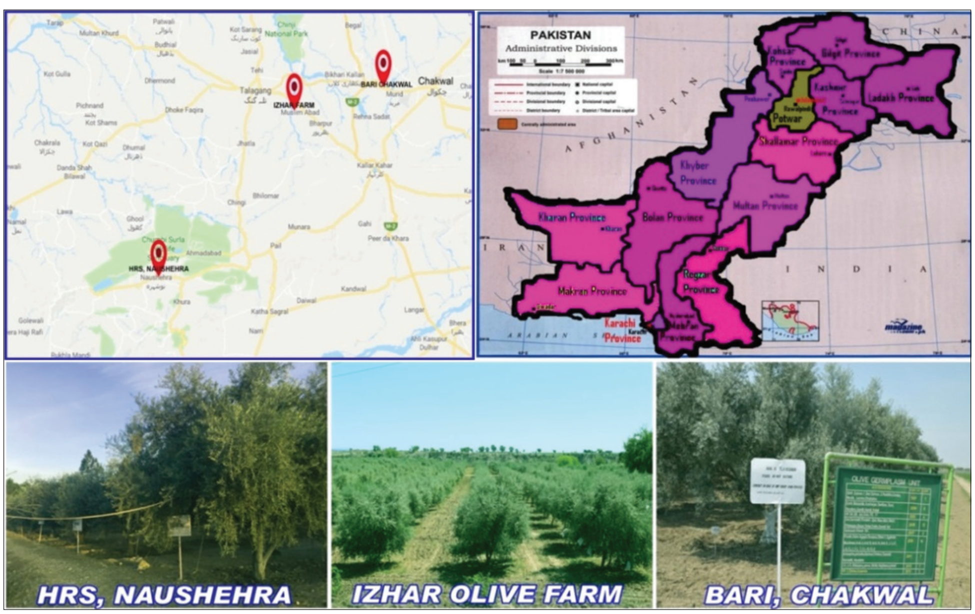

Fig 1. Pictorial view of three experimental locations selected for study.

Table 1: Soil physico-chemical status of three locations used for olive cultivation under study

Type/Quantities	Location-1	Location-2	Location-3
Texture class	Loamy	Sandy Loam	Sandy clay loam
pH	8.1	7.9	8.00
Organic matter (%)	0.63	0.55	0.78
Nitrogen (%)	0.05	0.04	0.06
Phosphorus (ppm)	3.1	2.6	3.0
Potassium (ppm)	121	110	115
Electrical conductivity (dSm^{-1})	0.61	0.55	0.64

Climatic conditions of the studied locations

Variability in agro-climatic conditions was found among locations (Fig.S1-3). Location-2 received the maximum rainfall (1189 mm) and summer temperature (37.51 °C). Location-1 was found with medium rainfall (786 mm) and summer temperature (36.6°C). While minimum rainfall (525 mm) and temperature (36.05 °C) was noted at location-3. The maximum temperature was noted in the first week of June at all locations with the values of 43 °C, 45 °C and 41°C at location-1-3 (Fig. S2), respectively, while the minimum temperature was noted at location-3 followed by location-1 and location-2 in January (Fig. S3). The driest period was noted from October to February while the highest rainfall was received from July to August at all three locations. In the comparison of both year at location-2 more rainfall received in 2018 (1384 mm) as compared to 2017 (995 mm) while location-1 and location-3 received high rainfall in 2017 (806 mm & 638 mm) and low rainfall in 2018 (766 mm & 412 mm), respectively (Fig. S1).

Phenological attributes and yield traits

The effect of cultivar, location, and interaction between them was estimated on fruit set, fruit weight, yield per tree, and oil content. The results were found significant for all the parameters (Fig. 2A-D). The summer temperature of 2018 was lower than 2017 at all locations due to which fruit set and yield per tree were found in increasing trend rather than fruit weight and oil contents. The fruit weight was found in the decreasing trend might be due to high yield. At location-3 where summer temperature and rainfall were less, the fruit weight was recorded maximum (Fig. 2B). The varieties behave differently with reference to location and season. The variety of Coratina and Frantoio depicted significantly higher fruit set and yield in warmer climatic regions (Location-1 and Location-2), while varieties Leccino and Ottobratica showed better results in the cooler region (Fig. 2A and C). The behavior of variety Frantoio was found unstable with respect to season and location. Overall, all the varieties showed significantly less yield at location 2. The yield of varieties of Frantoio and Coratina in 2018 was found at a lower level might be due to alternate bearing (Fig. 2A and C).

The cultivars showed significant differences among all three locations regarding oil content in both the seasons (Fig 2D). The variety of Frantoio and Coratina resulted in good oil content at location-1 and location-3 having low summer temperature and rainfall as compared to location-2 having high summer temperature and rainfall (Fig. 2D). The variation between the seasons was not significant. Variety Leccino showed abrupt behavior with reference to summer temperature. Huge fluctuation in oil content was noted but the performance was found good when the temperature was on the lower side. However, at location-3 in 2017 and 2018 where the temperature was down with low rainfall even than oil content was minimum might be due to heavy production in the cooler region (Fig. 2D).

Disparity was observed among all the parameters in all tested olive cultivars at three locations (Fig 2 A-D). We ranked the varieties based on their performance regarding oil and fruit productivity and found that Leccino may be avoided growing in warmer climatic conditions while Coratina and Frantoio may be selected for all warmer and cooler areas.

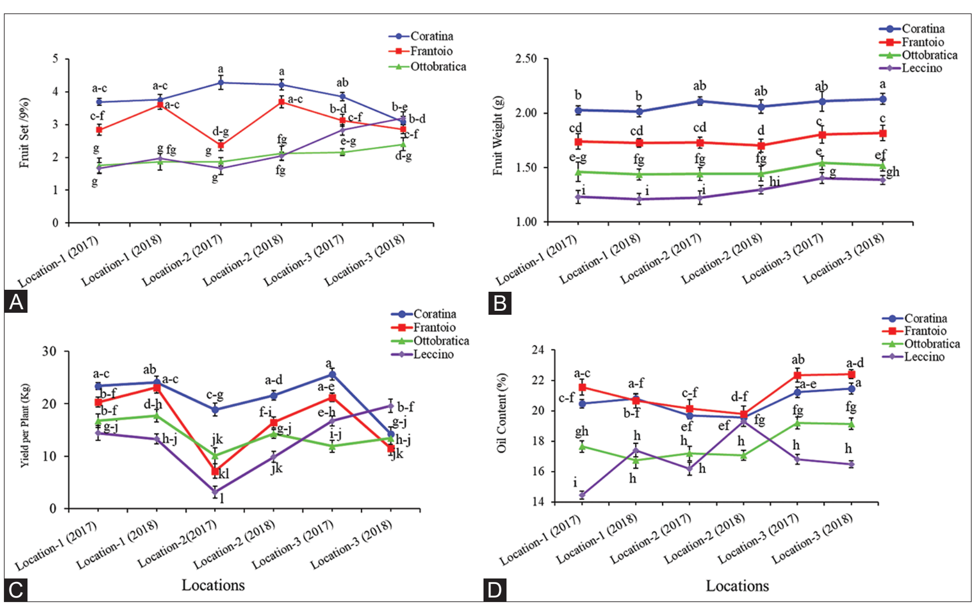

Fig 2. Olive varietal responses towards fruit set (A), fruit weight (B), yield per tree (C) and oil contents (D) at all three locations during 2017 and 2018.

Oil quality and fatty acid composition

Characterization of olive cultivar for olive oil quality and fatty acid composition were measured in relation to high summer temperature and fluctuation in rainfall (Fig 3 & 4; Table 2). We estimated the acid value in different cultivars at all locations. During 2017 and 2018, acid value varied among cultivars and locations. In general, the acid value was found double at location-2 as compared to location-3 in almost all the varieties. The acid value was in between at location-1. The lowest acidity was measured in the oil extracted from a variety of Coratina at location-3 in both the years followed by variety Frantoio and Leccino (Fig. 3). Variety Ottobratica depicted the lowest acid value in the warmer region as compared to the cooler region. The acid value demonstrated a direct relation to high temperature and low rainfall. Variety Frantoio and Leccino showed the same pattern as variety Coratina, but both were statistical at par because the smallest difference was found in between Frantoio and Leccino. Overall, Coratina showed the lowest acid value at all locations in both seasons. In the comparison of locations, it was noted that location-3 is better quality having low temperature and low rainfall. The results for peroxide value were found more or less similar regarding locations. However, variety Leccino showed very poor performance at location-1 and 3 (Fig. 4).

The fatty acid composition was analyzed for all the varieties at all locations (Table 2). The main fatty acid component was found oleic acid in olive oil. Oleic acid has special importance in the quality parameter of olive oil as its heart-healthy and confers oxidative stability. During the 2017 and 2018 differences between locations regarding oleic acid extracted from olive oil. The oleic acid contents considerably differ among locations but less variation in olive varieties and years (Table 2).

The interaction between varieties × locations and varieties × years, and among varieties × locations × years were also found statistically significant. The Ottobratica variety exhibited higher value for oleic acid (77.01%) however the lower amount of oleic acid was recorded in Coratina variety (75.33%) whereas maximum oleic content was recorded in fruits harvested from location-3 (77.06%) and minimum value at location-2 (75.08 %). The higher value of oleic acid was noted in Ottobratica cultivar (78.80 %) during the 2^{nd} year of production and lower content was found in Coratina cultivar in the 1^{st} year of study. Overall, during 2018 level of oleic acid was higher than in 2017 for all the cultivars in all climatic conditions (Table 2).

The decreasing trend of oleic acid in the oil of all the varieties in high-temperature regimes accords with the

Table 2: Fatty acid composition of four varieties at three locations during the year of 2017 and 2018

Treatment		Palmitic acid (C16:0)	Palmitoleic acid (C16:1)	Stearic acid (C18:0)	Oleic acid (C18:1)	Linoleic acid (C18:2)	Linolenic acid (C18:3)
				2017			
Coratina	Location-1	16.25^{a}	0.70^{a}	0.60^{de}	74.65^{ab}	8.30^{bcd}	0.55^{bc}
	Location-2	16.85^{a}	0.80^{a}	0.85^{a-e}	73.00^{b}	5.70^{d-g}	0.60^{bc}
	Location-3	16.05^{a}	0.65^{a}	0.50^{e}	75.85^{ab}	4.65^{g}	0.45^{c}
Frantoio	Location-1	15.90^{a}	0.70^{a}	0.85^{a-e}	76.45^{ab}	7.75^{b-e}	0.65^{bc}
	Location-2	16.55^{a}	0.85^{a}	1.15^{a-e}	74.40^{ab}	6.00^{d-g}	0.70^{abc}
	Location-3	15.55^{a}	0.60^{a}	0.75^{a-e}	77.30^{ab}	6.05^{d-g}	0.60^{bc}
Ottobratica	Location-1	17.35^{a}	1.25^{a}	1.05^{a-e}	76.30^{ab}	9.65^{ab}	0.75^{abc}
	Location-2	17.65^{a}	1.30^{a}	1.35^{abc}	75.30^{ab}	5.45^{efg}	0.85^{abc}
	Location-3	16.95^{a}	1.20^{a}	0.90^{a-e}	77.40^{ab}	5.45^{efg}	0.55^{bc}
Leccino	Location-1	17.40^{a}	1.20^{a}	0.95^{a-e}	75.95^{ab}	6.80^{c-g}	0.70^{abc}
	Location-2	18.40^{a}	1.30^{a}	1.25^{a-d}	74.70^{ab}	6.65^{c-g}	0.80^{abc}
	Location-3	16.75^{a}	1.10^{a}	0.80^{a-e}	76.30^{ab}	7.25^{b-g}	0.60^{bc}
				2018			
Coratina	Location-1	17.20^{a}	0.80^{a}	0.70^{b-e}	75.55^{ab}	9.00^{abc}	0.60^{bc}
	Location-2	17.10^{a}	0.85^{a}	0.90^{a-e}	76.15^{ab}	6.00^{d-g}	0.65^{bc}
	Location-3	16.80^{a}	0.75^{a}	0.65^{c-e}	76.80^{ab}	4.90^{fg}	0.55^{bc}
	Location-1	16.65^{a}	0.85^{a}	0.90^{a-e}	76.95^{ab}	8.00^{b-e}	0.80^{abc}
Frantoio	Location-2	16.70^{a}	0.90^{a}	1.20^{a-e}	74.55^{ab}	6.20^{d-g}	0.80^{abc}
	Location-3	15.80^{a}	0.70^{a}	0.80^{a-e}	77.65^{a}	6.20^{d-g}	0.65^{bc}
	Location-1	17.50^{a}	1.55^{a}	1.20^{a-e}	76.90^{ab}	11.15^{a}	0.85^{abc}
Ottobratica	Location-2	17.85^{a}	1.55^{a}	1.45^{a}	77.40^{ab}	5.70^{d-g}	0.90^{ab}
	Location-3	17.05^{a}	1.25^{a}	0.95^{a-e}	78.80^{a}	5.55^{efg}	0.60^{bc}
	Location-1	17.60^{a}	1.32^{a}	1.03^{a-e}	76.95^{ab}	7.75^{b-e}	0.80^{abc}
Leccino	Location-2	18.65^{a}	1.40^{a}	1.40^{ab}	75.20^{ab}	7.25^{b-g}	1.10^{a}
	Location-3	17.45^{a}	1.15^{a}	0.85^{a-e}	76.45^{ab}	7.40^{b-f}	0.70^{abc}

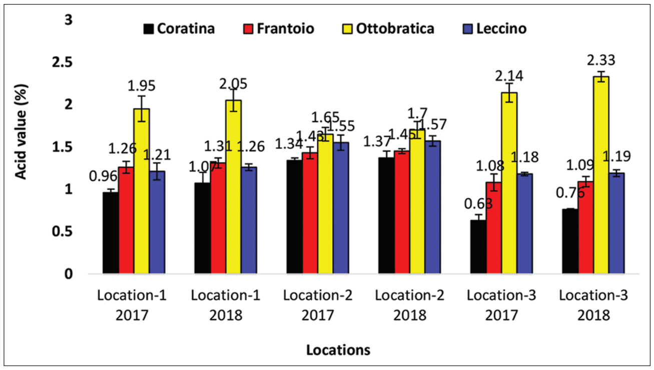

Fig 3. Free fatty acid contents (%) of extra virgin olive oil (EVOO) from different varieties during the years 2017 and 2018.

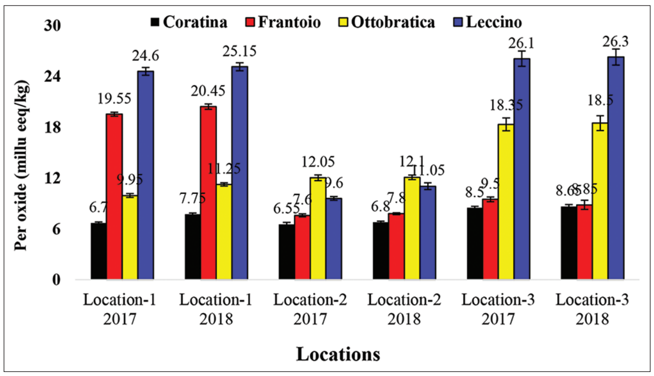

Fig 4. Peroxide (milli eq/kg) values of extra virgin olive oil (EVOO) from different varieties during the years 2017 and 2018.

increasing trends of linoleic acid and palmitic acid extracted at the same location. The values of linoleic acid and palmitic acids were 2% and 1% higher at location-2 as compared to the other two locations respectively. No statistically significant difference among varieties and locations regarding oleic acid, palmitic acid, and palmitoleic acid was found. However, varieties showed significant results regarding linolenic, linoleic, and stearic acid. A negative correlation of oleic acid was observed with acid value and stearic acid while a strong significant positive correlation with palmitic, linolenic, and palmitoleic acids. In conclusion, we found the negative impact of high temperature on olive oil quality by increasing the acidity, palmitic, palmitoleic, stearic and linolenic acids and by decreasing the value of oleic acid and linoleic acid (Table 2).

Cluster analysis

The dendrogram from UPGAMA analysis depicted two main groups on the basis of oil quality parameters and fatty acid profiling (Fig. 5). The glance of the fig.5 depicted that there were constructed, two main groups. Group-I contained two subgroups (A and B) while group-II contained three subgroups (C, D and E). The performance of varieties could be clearly differentiated through this cluster analysis. The variety Leccino showed

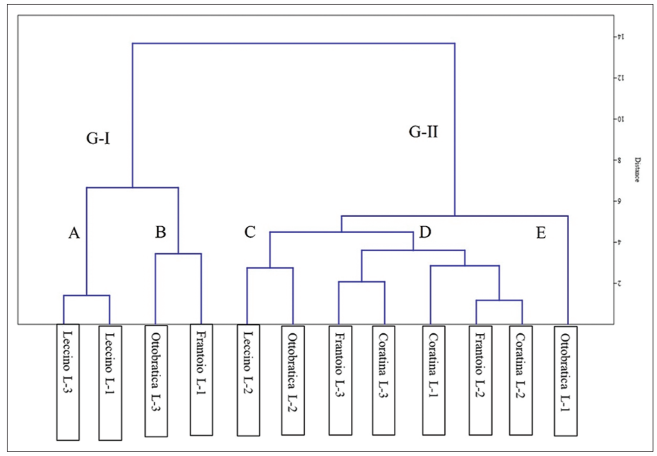

Fig 5. Dendrogram of three different locations of four exotic cultivars resultant from UPGMA analysis and contrast matrix of oil quality and fatty acid profiling parameters under study.

the same behavior at location-1 and location-3 (G-I, A) while varieties Coratina and Frantoio depicted similar performance at location-2 and location-3 (G-II, D). The variety Ottobratica was found in separate in subgroup under the main group-2, however, its performance was similar to Leccino and Frantoio at location-2 and location-3 (G-II, C and D), respectively.

Cultivar vector view of bi-plot.

The bi-plot obtained from PCA based on quality and free fatty acid profiling indicated that the first principal component (PC-1) consisted of 91.99 % of the variance while the second principal component (PC-2) accounted for 4.63 %, thus Fig. 6. presented the 96.62% of the total difference among them. Principal component analysis of the models exposed separation of three locations and four cultivars into three separate plots: a first plot consisted of varieties Frantoio and Leccino that was planted at location-1 and Leccino and Ottobratica that was planted at location-3, a second plot contained the varieties Ottobratica, Coratina and Leccino that was planted at location-1 and location-2 respectively. The last third and largest plot consisted of varieties Frantoio and Coratina at location-2 and location-3 and Ottobratica at only one location i.e location-1. The maximum projection was detected in Ottobratica and Coratina which were planted at location-1 and location-3, respectively; while the minimum outcrop was perceived for variety Leccino at location-1 and location-3. A positive correlation was observed in variety Leccino, Frantoio, and Ottobratica at both locations-1 and 3, while all remaining treatments were found negatively correlated at three locations.

DISCUSSION

The agro-climatic condition of a specific region has a profound effect on plant productivity and quality attributes

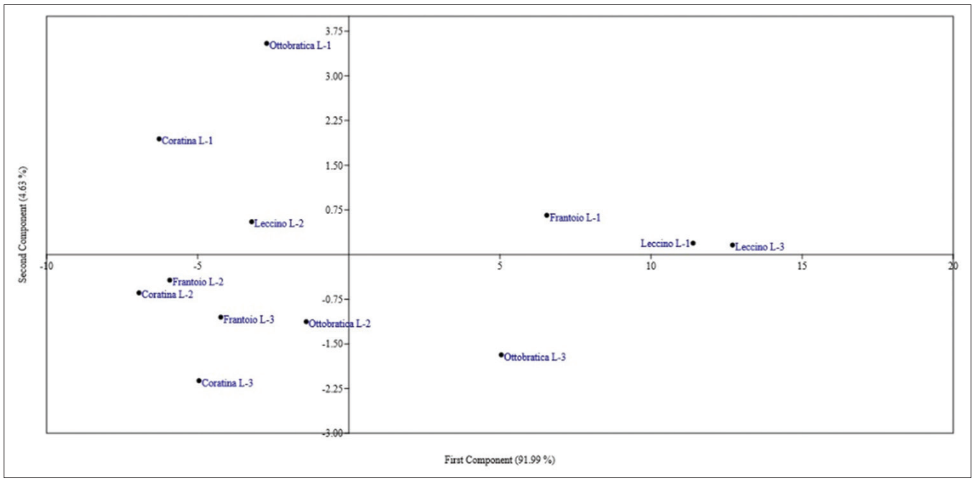

Fig 6. Diagram showing projection and relationship of three different locations of four exotic cultivars based on oil quality and fatty acid profiling.

of fruit (Khalil et al., 2022). Olive oil production is highly dependent upon the fruit load, average fruit weight, and oil accumulation at maturity along with the prevailing environmental condition (Ahmed et al., 2019). The varietal behavior was addressed in relation to different locations having the varying intensity of rain and temperature. The high-temperature effect upon olive oil content, yield per tree, and oil composition was observed. The results depicted that variety Coratina and Frantoio performed well at all locations while variety Leccino showed better results in the cooler area. Biochemical composition analysis of olive oil is important to evaluate the oil quality of different olive varieties (Taha and Ahmed 2016; Kiritsakis et al., 1998). Oleic acid and acidity were found in increasing trend with the increase of temperature in almost all the varieties. The results from our study are in line with previous studies that variation in oil content is directly correlated with genotype, yield/plant, fruit flesh weight, and year due to variation in temperature (Gregoriou, 1996; Lavee and Wodner, 2004; Taha and Ahmed 2016). However, the contradiction lies with the findings of Lavee and wonder (2004) that oil content is not affected by maturity stage and fruit size.

The physiology of fruit, oil accumulation, and composition under the high or low-temperature regime is still not clear however we found a strong correlation of maximum summer temperature and monsoon rainfall on fruit weight and oil quality. The quality of the oil was better in any season or location where low temperatures and rainfall were noticed. The oleic acid depicted a negative correlation with low temperature.

It is a well-known fact that the high concentration of free fatty acids (FFA) in oil can reduce the shelf life because it acts as pro antioxidant Scarpellini et al., (2005) and could lead to autoxidation of oil. The same is true for peroxide contents that higher the value of peroxide and hydroperoxides, the higher is the rate of auto-oxidation of oil, therefore, the oil of variety with minimum acid value is considered as good quality oil. In our study, the extra virgin olive oil **(**EVOO) from variety Coratina was found best with minimum FFA and peroxide values. Significant differences were observed among varieties and location for these values and findings are supported by previous studies that FFA and peroxide values directly linked with variety and geographical location (Perri et al., 2012; Kiritsakis et al., 1998). Previous finding reported that different geographical location significantly influences the quality parameter and physical properties of EVOO of Turkish, Portuguese, and Spanish cultivars (Gouvinhas et al., 2017; Sousa et al., 2015; Dagdelen et al., 2013; Vinha et al., 2005). According to previous studies, the oil characteristic and its quantity depend upon the location and genetic background of a cultivar 33-35 (Awan and Rab, 2014; Zarrouk et al., 2009; Al-Juhaimi et al., 2017). Monounsaturated fatty acid (oleic acid) has a significant value among fatty acid composition that differentiated olive oil from the rest of the edible oils.

The results from data depicted that non-significant differences occurred among the olive varieties to produce oleic acid but varied significantly with the locations. The production area, the climate, fruit maturity stage influences the FA composition of EVOO as reported previously (Cetinkaya et al., 2017). Moreover, the olive oil quality and behavior are highly influenced by the genotype ripening stage, the process involved in oil extraction in the industry as well as on environmental conditions like temperature, air, and light (Mousa et al., 1996; Lanteri et al., 2002; Beltran et al., 2004; Boskou et al., 2006). The EVOO extracted from cultivars grown in Pakistan was found to be rich in oleic acid and low in palmitic and linolenic acid and the same trend was reported for Greek, Italian, and Spanish EVOO whereas Tunisian EVOO have a high percentage of palmitic and linoleic acids and lower in oleic acid. In light of the above discussion, therefore we can summarize that the olive plant is sensitive to high summer temperatures regarding productivity and oil quality.

CONCLUSION

The present investigation provides insightful information about the influence of geographical locations on the growth, yield, oil content and fatty acid profiling in four olive cultivars. Our results showed positive relation of rainfall and negative relation of temperature on the overall productivity and oil characteristics. High temperature declined oil content and enhanced the acid value in all the varieties. Significant decrease was noted in fatty acid composition due to change in temperature at different locations. Overall, Infulence of geographical locations have a foremost role in resolution of quality attributes of olive oil.

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Author contribution statement

MAI, MA and HA conceptualized the work and conceived the experimental design. MA and MRA, IH and QL collected samples and carried out formal analyses. MAU, MAK, HA and MA performed physiological, biochemical analysis, and performed statistical analysis MAI, QL, IH, and MA helped in the contributed to the writing, interpretation of the results and in the revision of the manuscript. All authors have read and agreed to the published version of the manuscript.

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