Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2018; 7(3): 3464-3469
Received: 17-03-2018
Accepted: 22-04-2018

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Effect of harvesting time on yield, quality and fatty acid profile of olive oil produced in foothills of Himalayas

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Abstract
Research was conducted to standardize maturity indices of olive (*Oleaeuropaea* L.) for harvesting of fruit and its impact on oil yield and quality. The cultivars selected for the study were Leccino, Messinese, Picholina, Etnea, Itrana, Coratina and Zatiuna. Standard protocols were followed for determination of quality parameters namely acid value, peroxide value, saponification value, iodine number and fatty acid profiles. The results obtained showed that the moisture content in the olive fruits decreased, whereas, oil content increased in all the olive cultivars under study as the maturity progressed. Furthermore, among the quality parameters of the oil studied, the iodine value was observed to decrease, while acid value, peroxide value, saponification value correlated positively with the maturity index. As regard to the fatty acid composition of the oil, level of palmitic acid decreased whereas the level of stearic acid and linoleic acid increased with the time of harvest. Oleic acid, the main component of the olive oil, also decreased towards the harvesting season.

Keywords: cultivar, fruit, maturity index, moisture, olive, oil quality

Introduction
Olives are in cultivation since trinity for the beneficial effects of its oil. In the last few decades, there has been an upsurge in consumption of olive oil, even in countries which don't have any history of olive cultivation (Mill, 2006) [11]. The popularity of the olive oil as the preferred oil for consumption purpose is largely due to the fact that it has got nutritional and health promoting benefits (Boskou, 2011) [3]. Olive oil is a natural blend of saturated and unsaturated fatty acids (Lazzez*et al*, 2008) [8]. The chemical composition and quality of virgin olive oil depends on location, climatic conditions, type of cultivar and extraction process (Dag *et al*., 2009) [5]. A grower is particularly interested about modifications in harvesting time and methods to improve the yield and quality of oil. During the ripening process, there is a marked change in the moisture percentage and oil content of the fruit and chemical composition of the oil (Salvador *et al*., 2001) [15]. The moisture percentage goes on decreasing and the oil percentage goes on increasing up to a particular point of maturity. The chemical characteristics and composition of fatty acids gradually change as the fruit ripens and it affects the overall quality of the oil. As the maturity of the olive fruit progresses, the oil becomes less stable due to an increase in the polyunsaturated fatty acids and a decrease in total polyphenol content. These fluctuations are of keen interest as they dramatically influence the oil quality as well as its shelf life (Ayton *et al*, 2007) [1]. The present study was planned to investigate the effect of harvesting time on yield and quality attributes of olive oil produced from olives grown in the foothills of Himalayas.

Materials and Methods
Plant material
The study was undertaken in the olive orchard of the Department of Horticulture at Advanced Center for Horticulture Development, Govindpura, district Ramban, Jammu. The experimental site is located at 33°15′N 75°15′E. Seven exotic olive cultivars namely Leccino, Messinese, Picholina, Etnea, Itrana, Coratina and Zaituna were selected for the study. Recommended doses of Farm Yard Manure and chemical fertilizers (Urea, DAP and MOP) were applied to the plants, besides spray of monocrotophos and borax to ward off the psylla infestation and better flowering and fruit set respectively (Tiku*et al*, 2010) [18]. Three trees for each variety were selected for the purpose of study.

Harvesting of olive fruit samples
The olive fruits were harvested at periodic fifteen days interval using mechanical shaking with hands starting with the date when the olive fruits have just begun to change their colour.

Moisture content
Ten fruits from each tree in a variety were weighed and dried at 60 °C. To aid the drying process, the fruits were pinched on all the sides. Moisture content (%) was determined by dividing the difference in the fresh and dry weight of the olive fruit by the fresh weight and expressing it in terms of percentage.

Maturity index
Maturation index was determined using 100 randomly picked olive fruits from 1 kg of freshly harvested olives. The olives were cut in to two halves to reveal the inner flesh and were sorted into categories (Boskou, 1996) [2]. The following equation was used to calculate the maturity index:

Maturity Index= $[(0 \times n_0) + (1 \times n_1) + \ldots\ldots + (6 \times n_6) + (7 \times n_7)/100]$

Where n is the number of fruits with that score.

Oil extraction
Oil was extracted using a standard procedure. Fruit sample was dried in an oven at 60 °C and crushed to a fine powder using pestle and mortar, before submission to Soxhlet's assembly for extraction of the oil. The oil content obtained is expressed as percent of fruit weight.

Olive oil analysis
Acid value of the oil was estimated according to method standardized by Cox and Pearson (1962) [4]. Saponification value was calculated according to William Horowitz (ed.) (1975) [20]. Peroxide value was estimated according to Cox and Pearson (1962) [4]. Iodine value was estimated according to William Horowitz (ed.) (1975) [20].

Fatty acid profiling of the oil
Fatty acids of the oil were estimated by Gas Chromatography (GC) analysis (Nucon GC equipped with a flame ionization detector and a SGE BPX 70 capillary column). Fatty acids identification was done by comparing the retention times with those of the standard compounds. Four major fatty acids C 16:0, C 18:0, C 18:1 and C 18:2 were considered in this study.

Data analysis
The observations were statistically analyzed by using Randomized Block Design method as given by Gomez and Gomez (1983) [7].

Results and Discussion
Maturity index (MI) of the olive cultivars showed significant variations on all the harvest dates (Fig 1). Cultivar Picholina recorded a maximum maturity index of 4.76 on the last harvest date (30th Oct.) which was in close proximity with the international standard for maturity index for olive fruit. The minimum maturity index value was recorded with the cultivar Itrana having a maturity index value of 4 on the last harvest date. To a naked eye, the fruit colour is an indication of maturity level expressed as maturity index. Ripening of the olive fruit is accompanied by the accumulation of anthocyanins. During ripening, oil content of the olive fruit increases whereas there is a reduction in the chlorophylls and carotenoids content due to decrease in the photosynthetic activity (Salvador *et al*, 2001) [15]. The accumulation of anthocyanins in the fruit is evident from the colour change of olive fruit from green to purple (Roca and Minguez-Mosquera, 2001) [13]. The progression in the maturity index was gradual in the first phase of the ripening process while it picked up after the second harvest date. The time of harvest plays a major role in the quality of the virgin olive oil production. Besides being the single most expensive field operation in the olive oil production (Rallo, 2009) [12], it also affects the total yield.

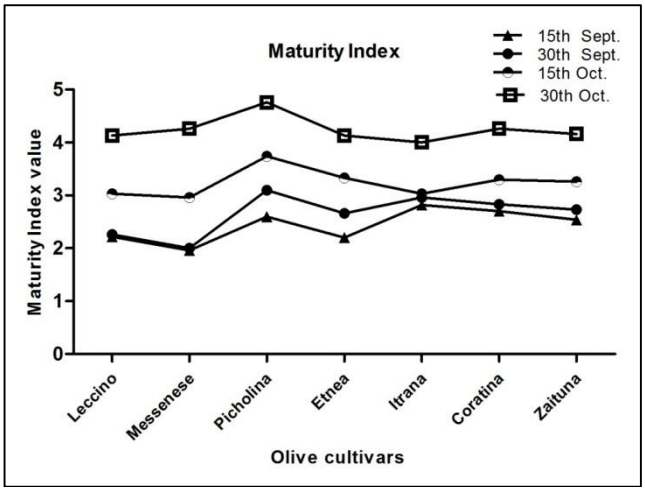
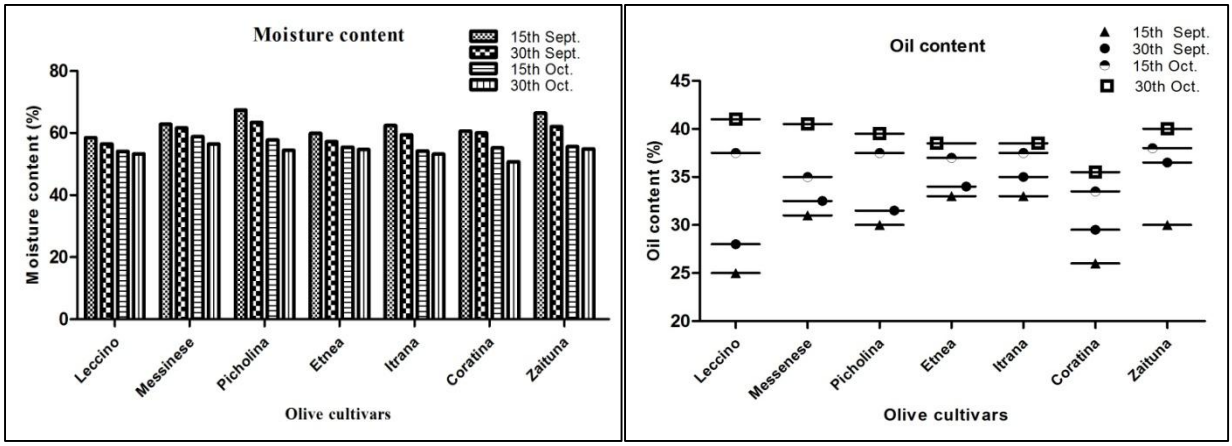


Fig 1: Variation in maturity index of different olive cultivars in correlation with the timing of the harvest

Significant differences were observed among the moisture contents of the fruits of different olive cultivars on the four harvest dates (Fig 2 a). The maximum moisture percentage was recorded in the fruits harvested at first harvest date (15th Sept.) in the variety Picholina with a moisture percentage of 67.44% which decreased to a value of 54.43 % on the last harvest date (30th Oct.). The minimum moisture percentage was recorded in the variety Leccino with a moisture percentage of 58.50 % which decreased to a value of 53.29 % on the last harvest date (30th Oct.). However, along the progression of the maturity period and during subsequent harvests, the moisture content percentage decreased considerably among all the olive cultivars. On the last harvest date (30th Oct.), cultivar Messinese recorded a maximum moisture percentage of 56.52 % whereas minimum moisture content was recorded with the variety Coratina with a moisture content percentage of 50.79 %. Comparatively, the maximum reduction in the moisture content percent was recorded with the variety Picholina with a moisture content reduction of 13.01 % between first and last harvest dates. Significance of moisture content of the fruit can be judged from the fact that a steep fall in fruit moisture level can lead to desiccation and cell breakdown which may lead to increase in free fatty acids and therefore poor oil quality (Mailer *et al*., 2005) [9].



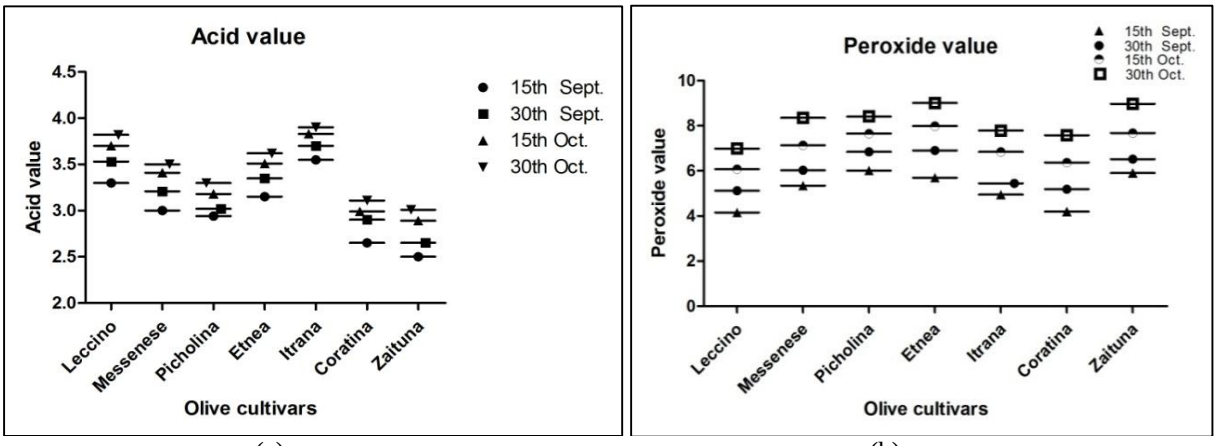
(a) (b)

Fig 2: Moisture content (a) and oil content (b) of olive fruit of various olive cultivars at different harvesting dates

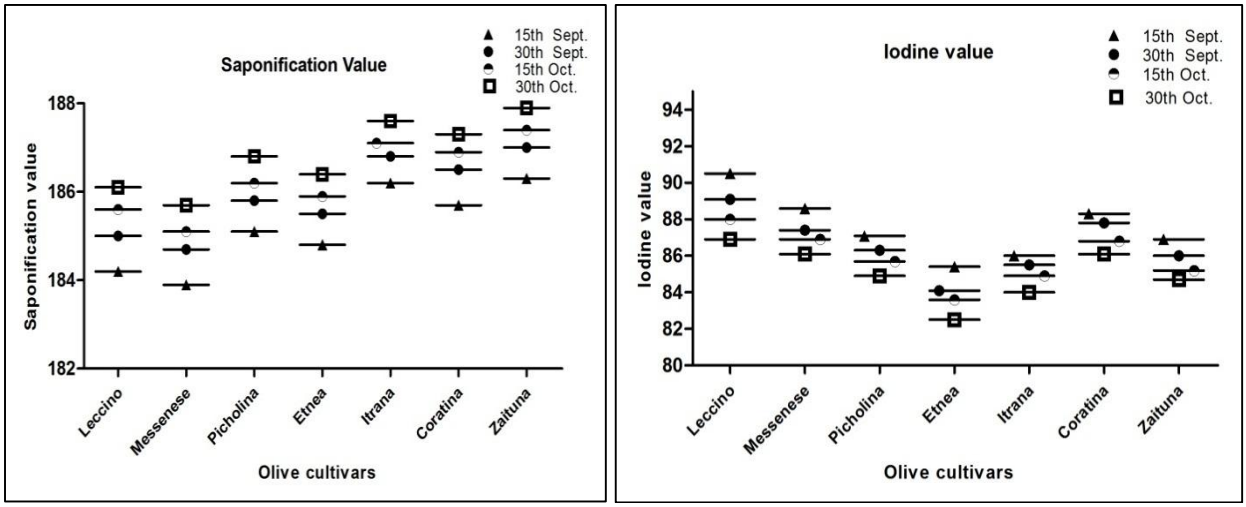
Oil content percentage also showed significant variations among all the olive cultivars under study (Fig. 2 b). Variety Leccino, having oil content percentage of 25 % at the first harvest date (15th Sept.) showed a maximum oil content percentage on the last harvest date (30th Oct.) with an oil content percentage of 41 % with an overall increase of 64 % in oil content whereas minimum oil content (35.5 % each) was recorded with the varieties Picholina and Coratina on 30th October. Oil accumulation in the olive fruits increased consistently during the growth period. This increase in the oil content may be attributed to the biosynthesis of triglycerises until the fruit reaches full maturity. During the beginning of the harvesting, oil content was markedly lower but at the end of the season, the fruits showed an increased oil content.

All the olive cultivars under study showed acid value above 3.0 on the last harvest date (30th Oct.) (Fig. 3 a). Acidity values recorded for the variety Itrana increased significantly from 3.55 at first harvest date (15th Sept.) to 3.9 at the last harvest date (30th Oct.) which was the maximum among all the olive cultivars at the last harvest. Minimum acid value was recorded for the cultivar Zaituna with an acid value of 3.01. A similar increase in acidity during the maturation period was reported by Yousfi*et al*, (2006) [21]. It has been shown that olives at later stages of ripening give oils with higher levels of acidity caused by the activity of internal lipases, and exhibit higher sensitivity to pathogenic infections and mechanical damage (Salvador *et al*, 2001) [15].

The influence of harvesting time on the peroxide value of the oils was determined (Fig. 3 b). Variety Etnea showed maximum increase in the peroxide value which increased from 5.7 to a final value of 9.01. Minimum peroxide value was recorded with the variety Leccino with a peroxide value of 6.99 at the last harvest date. The results thus obtained show a gradual increase in the peroxide value of the oils extracted on successive harvest dates and are in conformity with those obtained by Dag *et al*, (2010) [6]. The saponification value (Fig. 3 c) also showed an increasing trend towards the progressing harvesting dates. Maximum saponification value was recorded with the variety Zaituna which increased from an intitial value of 186.3 to a final value of 187.9 on the last harvest date. Variety Messinese recorded the minimum saponification value on the last harvest date with a value of 185.7. The iodine value (Fig. 3 d) showed a decreasing trend as the season progressed. Minimum iodine value was recorded with the variety Etnea which decreased from an initial value of 85.4 to a final value of 82.5, a decrease of 3.4% approx since first harvest to the last harvest. Variety leccino recorded maximum iodine value on the last harvest date with a value of 86.9 which decreased from an initial value of 90.5.



(a) (b)



(c) (d)

Fig 3: Oil characteristics (a) acid value (b) peroxide value (c) saponification value and (d) iodine value of olive cultivars at different harvesting dates

Major fatty acid accumulation

The qualitative and quantitative characterization of esterified olive oil harvested on periodic harvest dates showed four major fatty acids. It is already established that there is a change in the fatty acid composition of the olive oil extracted which is associated with olive fruit maturation. The major saturated fatty acid – palmitic acid- decreased from the initial harvest till the last harvest in Leccino, Messinese, Picholina and Etnea cultivars of olive (Fig 4 a). Maximum palmitica acid percentage was recorded in the variety Zaituna with a final value of 18.54 percent. Minimum palmitic acid percentage was recorded with the variety Leccino with an initital value of 18.54 percent and a final value of 15.08 percent, an overall decrease of 21.6 %. This drop in palmitic acid percentage coincides with the results described for a number of olive cultivars (Menz and Vriesekoop, 2010) [10]. This decline in the palmitic acid percentage along the progression of the harvest season can be attributed to the dilution effect, caused by a constant quantity of palmitic acid but rising levels of total fatty acids resulting in a reduction in the relative amount of palmitic acid bound to the triglycerides. However, cultivars Itrana, Coratina and Zaituna showed a slight increase in the palmitic acid percetage towards the last harvest date which differs from the reported trend with other olive cultivars.

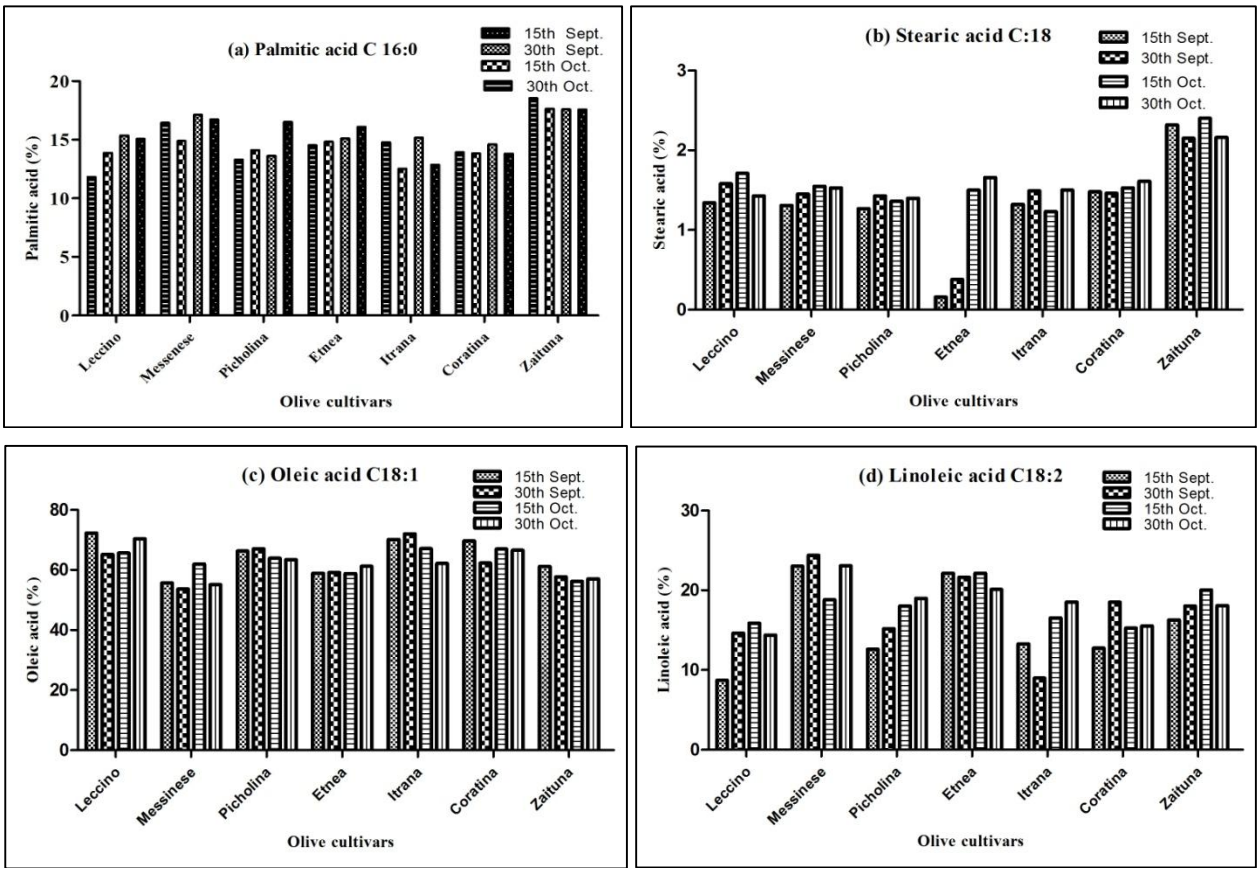


Fig 4: Periodic variation in fatty acid profile of olive fruit at different harvesting intervals (a) palmitic acid content (%) (b) Stearic acid content (%), (c) Oleic acid content (%) and (d) Linoleic acid content (%)

Stearic acid (C18:0) showed gradual increase in content along the progression of the harvest season in all the cultivars of olive except Zaituna (Fig 4 b). Maximuim stearic acid content was recorded in the variety Zaituna with a value of 2.16 at the last harvest. The stearic acid content of variety Picholina, which was minimum of all the cultuvars on the last harvest date was recorded to be 1.40 percent which increased from 1.27 percent. This trend of increase in the stearic acid percentage differs from the reported data on olive cultivars which indicates that stearic acid does not accumulate during the ripening process (Salas *et al*, 2000) [14].

Oleic acid (C18:1), which was high at the beginning of the harvest (first harvest date) showed a slight decrease in content during the ripening process with a maximum value of 70.39 percent being recorded with the cultivar Leccino (Fig 4 c). Minimum oleic acid percentage was recorded with the variety Messinese with a value of 55.07 percent.The decrease in the relative quantity of the oleic acid levels has also been recorded by other researchers (Menz and Vriesekoop, 2010) [10]. The only variation to this trend was observed with the variety Etnea which showed an increase of 3.94% in the oleic acid percentage since the first harvest date.

Linoleic acid (C18:2) increased in all the olive cultivars under study with the progression of fruit maturity, maximum being in the cultivar Messinese with a percentage of 23.08 percent at the last harvest (Fig 4 d). The minimuim linoleic acid percentage was recorded in the variety Leccino with a value of 14.38 percent. The results obtained coincides with the results reported for other conditions and locations (Menz and Vriesekoop, 2010) [10]. The increase in linoleic acid content may be related to the gradual reduction in temperature during the olive fruit maturity season. However, a slight decrease in linoleic acid content was observed with the cultivar Etnea between first and last harvest date. Overall, the variation in the fatty acid profiles may be attributed to the varietal difference between the olive cultivars (Tiku*et al*, 2013) [17].

Conclusions

In conclusion, olive being a highly sustainable crop for the hill agriculture needs to be studied more for utilizing the full potential of the crop. The low fruit set percentage and problem of fruit drop in the later stages of fruit ripening call for precise area specific timing of harvesting. The drop in the mature fruit is compensated by the increase in the oil percentage. The oil quality with respect to the acid value, peroxide value, saponification value and iodine value and fatty acids was well within the International standards for olive on the last harvest date. As per the observations made in this study with respect to maturity index, it is recommended that the harvesting of the mature fruits should not be carried before 30th of September in this part of the country.

Acknowledgements

Financial support by the funding agency, Indian Council of Agricultural Research and infrastructural support provided by SKUAST-Jammu under HTM-MM-1 project (2.41) on olive is duly acknowledged.

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