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Olive fruit dry matter and oil accumulation in warm environmental conditions

Isa Arji*
Crop and Horticultural Sciences Research Department, Kermanshah Agricultural and Natural Resources Research and Education Center, AREEO, Kermanshah, Iran
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ABSTRACT

The present study was carried out during 2007, 2008 and 2009 on 6 olive cultivars to investigate the process of oil and dry matter accumulation in response to warm and dry conditions in Dallaho Olive Research Station of SarpoleZehab, Kermanshah province, Iran. Results showed that oil begins to accumulate in the fruit from July, increases gradually through August and reaches its maximum as the fruit becomes completely black in November. Patterns of oil accumulation over the period of the study varied between cultivars. Dry matter acquisition was continuous and increased with a slow slope in all cultivars during fruit growth. Oil content correlated with the percentage of fruit dry matter, so that Roghani with the highest dry matter had the highest oil content in fresh fruit and dry matter. There was a linear relationship between dry matter and oil content in all cultivars. This relationship varied for different cultivars and was not strong however it can be an indicator of oil content. According to the results, olive cultivars showed different responses to warm conditions and oil accumulation was related to temperature. In conclusion, oil accumulation is a trait that can be influenced by environmental conditions and it depends on olive cultivars.

Keywords: Iran, Olive (*Olea europaea* L.), oil content, temperature.

تجمع ماده خشک و روغن در میوه زیتون در شرایط آب و هوایی گرم

عیسی ارجی*
بخش تحقیقات علوم زراعی و باغی، مرکز تحقیقات و آموزش کشاورزی و منابع طبیعی کرمانشاه، سازمان تحقیقات، آموزش و ترویج کشاورزی، کرمانشاه، ایران
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چکیده

این مطالعه به منظور بررسی تجمع ماده خشک و روغن در میوه زیتون در شرایط آب و هوایی گرم ایستگاه تحقیقات زیتون دالاهو سرپل ذهاب استان کرمانشاه، ایران برای سه سال متوالی ۱۳۸٦، ۱۳۸۷ و ۱۳۸۸ به اجرا در آمد. نتایج نشان داد تجمع روغن از تیر ماه آغاز گردید و در مرداد تدریجی بود تا این‌که در آبان به حداکثر خود رسید زمانی‌که میوه سیاه شد. الگوی تجمع روغن در طی دوره مطالعه بسته به رقم متغییر بود. تجمع ماده خشک در میوه پیوسته بود و در کلیه ارقام با شیب کمی افزایش نشان داد. میزان روغن با درصد ماده خشک میوه در ارتباط بود، جایی‌که رقم روغنی با بیشترین درصد ماده خشک میوه بالاترین درصد روغن در ماده تر و خشک داشت. رابطه خطی بین میزان روغن و درصد ماده خشک در کلیه ارقام وجود داشت. این رابطه برای ارقام متفاوت بود و بسیار قوی نبود، اما می‌تواند به‌عنوان شاخص میزان روغن محسوب گردد. بر اساس نتایج ارقام عکس‌العمل متفاوتی در رابطه با شرایط آب و هوایی گرم نشان دادند و تجمع روغن در ارتباط با درجه حرارت بود. بطور کلی روغن صفتی است که بسته به رقم تحت تأثیر شرایط محیطی قرار می‌گیرد.

واژه‌های کلیدی: ایران، زیتون، میزان روغن، درجه حرارت.

* Corresponding author E-mail: issaarji@gmail.com

Introduction

Olive (*Olea europaea* L.) tree is an evergreen tree, native to the Mediterranean region. Its cultivation has expanded in various regions in Iran, due to higher olive oil demand in recent years. However, the cultivation of olive tree is limited because of the harsh environmental conditions and water scarcity in most of the new olive plantation areas (Arji & Arzani, 2008). The limitations of water as well as long hot summers in these regions have led to poor quality of fruit and oil (Khaleghi *et al.*, 2015; Saadati *et al.*, 2013). Despite good vegetative growth, some olive varieties do not produce acceptable amount of oil. This is due to environmental conditions and response of genotypes.

Climate influences all of the physiological processes of the plant (Osborne *et al.*, 2000). Various environmental factors affect plant growth and development differently. It has been concluded that temperature regulates plant growth and development processes, so that the rate of plant development is mainly dependent on temperature (Ritchie & Ne Smith, 1991). Temperature has been proposed as the most important variable that impacts phenological changes (Young & Lees, 1992). High temperature coincides with relatively low humidity which has negative impact on fruit growth and oil accumulation of olive plant (Arji, 2015). A relationship has been reported to exist between lipid composition and incubation temperature for algae, fungi and higher plants. Exposing Arabiodopsis plant to high temperatures decrease the total lipid content to about one-half (Somerville & Browsw, 1991).

Olive (*Olea europaea* L.) growth and metabolism are affected by changes in environmental temperature. The best areas for olive production have mild winters and long, warm, dry summers (Sibbett and Osgood, 1994). Growing olive and producing its oil are more common in those parts of Iran, which have suitable climatic characteristics for cultivating olive tree (Arji, 2015). These areas show mild winters and long and dry summers. Cimato *et al.* (2001) stated that olive trees need specific temperature patterns for optimal growth. Temperature requirements can be roughly defined as about +2-4°C (minimum), 14-18°C (Maximum) for fruit set, 25-28°C for optimal photosynthesis and growth during summer and autumn and winter temperatures should not be lower than -5°C for prolonged periods.

Plant vegetation ceases under temperatures higher than 32°Cand the first cellular damage can be seen when it exceeds 44°C (Mancuso & Azzarello, 2002). Olive metabolicand the photosynthetic activities reach a maximal level when it is exposed to an optimal range of temperature between15°C and 30°C (Krueger, 1994). Laboratory findings by Bongi and Long (1987) show that there was a reduction of 80% in quantum yield of olive leaf photosynthesis occurs when they were exposed to intense light and high temperature (38°C). According to Krueger (1994) findings respiration is catalyzed by enzymes that are temperature sensitive and there is a positive trend line when the temperature range is about 10°C to 30°C. Respiration is doubled by each 10°C increase in temperature and at higher temperatures, the enzymes can be denatured. Many researchers have explained that, olive reproductive success can be limited by excessive temperatures of about 30–35°C

(Cuevas, 1994; Martin *et al.,* 1994). Martin *et al.* (1994) stated that flowering, pollination and fruit set of olive is damaged by high temperatures when olive flower buds are developing, especially if these temperatures are accompanied by dry and windy conditions. The growth of olive pollen tubes is maximal at 25°C, while temperatures higher than this can cause negative influences on it (Cuevas, 1994; Koubouris *et al.,* 2009). It is important to consider that both the metabolic activity and the photosynthetic activity of the olive are maximal across an optimal range of temperature between 15°C and 30°C (Krueger, 1994).

The precursors of oil biosynthesis in olive fruit cells are sugars (Conde, 2008). Young mesocarps contain about 20% sugars (dry matter), but this content decreases when oil accumulation begins (Conde, 2008). There are two sources of carbohydrates for fruit growth and lipid biosynthesis in olive. The major one is provided by sugars translocated in the phloem from mature leaves to sites of storage. The secondary source is sugars formed by photosynthesis in the fruits themselves (Sánchez, 1994). Sarpole Zehab environmental condition is warm and dry during summer when fruit growth and oil accumulation take place in olive. The oil accumulation changes markedly with regards to cultivar and environment. The main objective of this study was determining oil accumulation of different olive cultivars in warm environmental conditions. Assessment of suitable cultivars for oil accumulation was another aim of this research.

Materials and Methods

This experiment was conducted in Dalahv Olive Research Station of Sarpol-e-Zehab (longitude: 45º 51´ E, latitude: 34º 30´ N, altitude: 570 m) oneight years old Iranian and foreign olive cultivars, during three successive years 2007, 2008 and 2009. Cultivars were Roghani, Zard, Shenge, Baladi, Sevillano and Koroneiki. Olive trees were planted in a 6*6 spacing distance in a randomized complete block design with three replications in 2000. Meteorological data were collected from Sarpole Zehab weather station (Table 1 and 2).

Samples (100 fruits) were picked up from south facing side of trees (Anon, 1997) approximately every two weeks from 21 July till 21 November during the three successive years. Samples were divided to three subsamples of 30 fruits. Fresh and dry weight of each subsample was measured. Dry weight and moisture content was determined by oven-drying at 80±1°C for 48h (Anon, 1997). Oil content was determined by Soxhlet method with 250 ml diethyl ether during 8h (Dag et al 2013). Oil contentwas calculated on a fresh and dry weight basis. Recorded data were analyzed by using SAS 9.3 software and means were compared by LSD ($P<0.05$).

Results and Discussion

Results showed that different olive cultivars responded differently to warm and dry environmental conditions in Sarpole Zehab. Accumulated fruit dry matter varied with olive cultivar, so that final fruit dry matter ranged from 35–47% based on the cultivar. Fruit dry matter accumulation trend was different in divese cultivars. Compared with the rest, Roghani, Baladi and Zard had the highest dry matter, i.e. more than 40% (Table3).

Oil accumulation pattern was similar in all cultivars, but the rate of oil accumulation varied between cultivars (Table3). Roghani and Zard had the highest oil content (40-45% DW and 16-20% FW) compared with the others cultivars (less than 32% DW and 13% FW). Oil content increased as dry matter increased in all cultivars but it was higher for Roghani and Zard cultivars. Oil accumulation was related to fruit dry matter so that cultivars with higher fruit dry matter had the highest amount of oil based on DW or FW. Mickelbart and James (2003) stated that there the trends of dry matter and oil accumulation varied in different olive cultivars. The results of the present study were in agreement with those obtained by Desouky *et al.* (2010), as they found that dry matter accumulation occurs in olive fruit till harvesting time for Arbequina, Bouteillan and Koroneiki.

The relationship between oil content and the percentage of DM varied in different cultivars, when expressing oil content on a DW basis as a function of % DM, (Figure 1). The relationship between oil content and % DM was strongest in 'Roghani'(R^2=0.663) for oil content expressed on a DW, followed by 'Baladi' (R^2=0.5984), 'Shenge' (R^2=0.5571), 'Koroneiki' (R^2=0.5473), 'Sevillano' (R^2=0.4511) and 'Zard' (*R2*=0.4206). So, % DM test can be used as an indicator of olive fruit maturity based on a relatively good relationship between oil content and DM percentage. This relationship was reported for different olive cultivars by Mickelbart and James (2003). They stated that the relationship between oil content and DM percentage was stronger than the relationship between oil content and color.

Olive oil quantity and quality depends on many factors, among which environment, genetic, agronomic and technological factors play important roles. Temperature is very important among environmental factors. Oil yield is economically significant for growers, but it is affected by environmental conditions and cultivars. Oil accumulation was presented based on cultivar and temperature in figure 2. Oil accumulation started from July and was very slow during warm month till the temperature begin to decrease from end of August and then oil accumulation rapidly increased to the end of November when the fruit was in the black stage (Figure 2).

Table 1. Meteorological data of Min, max and mean temperature for Sarpole Zehab, Kermanshah, Iran during the trial period

	Month												
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Agu	Sep	Oct	Nov	Dec	Mean
	Average of Minimum Temperature (^{o}c)												
2007	1.5	4.9	6	10	16.8	20.4	23.9	22.6	17.6	14.1	6.8	3	12.3
2008	-0.2	3.1	8.4	12.4	15.6	20.3	23.1	24.2	20.6	14.9	8.8	3	12.8
2009	1.4	5.7	6.7	9.7	15.7	22.1	23.7	21.2	17.5	13.4	8.8	6.4	12.7
	Average of Maximum Temperature (^{o}c)												
2007	13.2	15.5	19.3	23.6	35.1	40.5	41.6	42.1	39	32.9	23.3	16.4	28.6
2008	10.4	16.1	25.8	30.4	33.5	40.1	42.5	43.1	37.6	30.2	21.3	16.9	29
2009	14.6	17.4	20.4	24.4	33.3	39.1	40.6	40.9	34.9	31.5	20.7	17.2	28
	Mean Temperature (^{o}c)												
2007	7.3	10.4	12.6	16.8	26	30.4	32.7	32.4	28.3	23.5	15	9.7	20.4
2008	5.1	9.6	17.1	21.4	24.6	30.2	32.8	33.6	29.1	22.6	15	10	20.9
2009	8	11.8	13.6	17.1	24.5	30.6	32.2	31	26.2	22.5	14.7	11.8	20.3

Table 2. Meteorological data of Relative Humidity and precipitation for Sarpole Zehab, Kermanshah, Iran during the trial period

	Month												
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Agu	Sep	Oct	Nov	Dec	Mean
	Average Relative Humidity %												
2007	71	74	63	61	45	28	26	28	29	38	48	64	48
2008	71	57	50	36	31	22	22	24	32	46	66	57	43
2009	61	65	60	60	39	22	25	25	37	41	71	75	48
	Average Precipitation (mm)												Sum

2007	66.5	66	33.8	80.5	22.5	1	0	0	0	0	0	23.3	293.6
2008	81.7	48.7	14.3	1.9	1.9	0	0	0	0.2	90.7	43.4	6.5	289.3
2009	22.7	44.2	30.8	52.1	1	0	0	0	9.6	52.4	86.3	63.5	362.6

Table 3. Olive oli and fruit dry matter accumulation during three successive years 2007, 2008 and 2009 in different cultivars

Cultivar	Sampling Time	Oil% (Fresh Weight)	Oil % (dry weight)	Fruit Dry Matter %	Cultivar	Sampling Time	Oil% (Fresh Weight)	Oil % (dry weight)	Fruit Dry Matter %
Baladi	21-Jul	1.63 uv*	4.68 z	34.62 m-u	Shengeh	21-Jul	1.30 v	4.09 z	31.84 tuv
	06-Aug	2.99 qrs	8.34 vw	35.85 k-r		06-Aug	2.02 stuv	6.13 xyz	32.97 r-v
	21-Aug	3.39 pqr	9.36 uv	36.28 k-r		21-Aug	2.20 stuv	6.64 xy	33.21q-v
	06-Sep	4.94 no	13.74 s	36.06 k-r		06-Sep	3.49 pqr	10.43 tu	33.45 p-v
	21-Sep	7.05 l	18.8 pq	37.48 g-n		21-Sep	5.68 mn	16.01 r	35.46 l-s
	07-Oct	8.73 k	23.41 n	37.29 h-o		07-Oct	8.20 k	22.85 n	35.89 k-r
	22-Oct	11.31 fg	29.48 ij	38.39 f-l		22-Oct	10.27hij	28.83 ij	35.63 l-s
	06-Nov	13.16 e	32.69 ef	40.23 d-i		06-Nov	11.49 f	31.33 efg	36.68 i-o
	21-Nov	13.42 de	32.05 ef	41.84 cde		21-Nov	11.78 f	32.16 ef	36.63 k-q
Rowghani	21-Jul	2.13 stuv	5.26 yz	40.53 d-h	Koroneiki	21-Jul	1.34 v	3.97 z	33.85 o-v
	06-Aug	3.61 pq	8.86 uv	40.79 c-g		06-Aug	2.08 stuv	5.93 xyz	35.10 l-t
	21-Aug	4.24 op	10.27 tu	41.39 cdef		21-Aug	2.33 stuv	6.59 xy	35.51 l-s
	06-Sep	8.49 k	20.17 op	42.15 cde		06-Sep	4.21 op	11.64 t	36.16 k-r
	21-Sep	10.89 f-j	25.32 lm	42.98 bcd		21-Sep	5.97 m	16.44 r	36.32 k-r
	07-Oct	14.25 d	32.89 e	43.37abcd		07-Oct	8.02 k	21.22 o	37.74g- p
	22-Oct	18.09 b	41.09 bc	43.97abc		22-Oct	9.99 j	25.51 l	39.20 e-k
	06-Nov	20.37 a	44.44 a	45.83ab		06-Nov	10.92 f-j	28.34 jk	38.53 f-l
	21-Nov	19.75 a	42.62 b	46.34a		21-Nov	11.75 f	30.06 ghi	39.14 e-k
Zard	21-Jul	1.91 tuv	5.38 yz	35.62 l-s					
	06-Aug	2.22 stuv	6.17 xyz	35.88 k-r					
	21-Aug	2.58 rstu	7.23 wx	35.79 k-r					
	06-Sep	5.35 mn	14.55 s	36.83 j-p					
	21-Sep	7.74 kl	21.12 o	36.60 k-q					
	07-Oct	10.16 ij	27.27 k	37.27 h-o					
	22-Oct	11.66 f	31.2 fgh	37.42 h-n					
	06-Nov	13.81 de	36.97 d	37.35 g-m					
	21-Nov	16.20 c	40.42 c	40.10 d-j					
Sevillano	21-Jul	1.77 uv	5.82 xyz	30.62 v					
	06-Aug	2.25 stuv	7.09 wx	31.70 uv					
	21-Aug	2.92 qrst	9.23 uv	31.67 uv					
	06-Sep	4.32 op	13.34 s	32.36 stuv					
	21-Sep	5.76 mn	17.48 qr	33.00 r-v					
	07-Oct	8.09 k	23.91 mn	33.83 n-u					
	22-Oct	10.36 ghij	29.7 hi	34.85 m-u					
	06-Nov	11.02 fghi	31.38 efg	35.11 l-t					
	21-Nov	11.24 fgh	31.68 ef	35.49 l-s					

* Means in each column with the same letters are not significant at probability level of 5%.

Oil accumulation pattern was similar for all studied cultivars but the rate of accumulation and its amount were different in different cultivars. Roghani and Zard had the highest rate of accumulation compared with others. Oil accumulation was influenced by temperature, i.e. when the mean temperature augments to more than 30^{o}C, it was very slow or inhibited as shown in Figure 2.

Connor & Fereres (2005) reported that olive oil accumulation started approximately in the phase of pit hardening which confirms the result of this study. Beltrán *et al.* (2004) stated that the oil accumulation profile in olive changes markedly with regards to cultivar and year. Their results are in line with ours with respect to the correlation of oil accumulation with the cultivar and year. According to Dag *et al.* (2011) oil accumulation profiles throughout ripening stages were dependent on fruit load, growing season characteristics and above all, variety. This is further affirmed by the results of the present study through evaluation of oil accumulation during fruit growth of cultivars in three consecutive years (2007, 2008 and 2009).

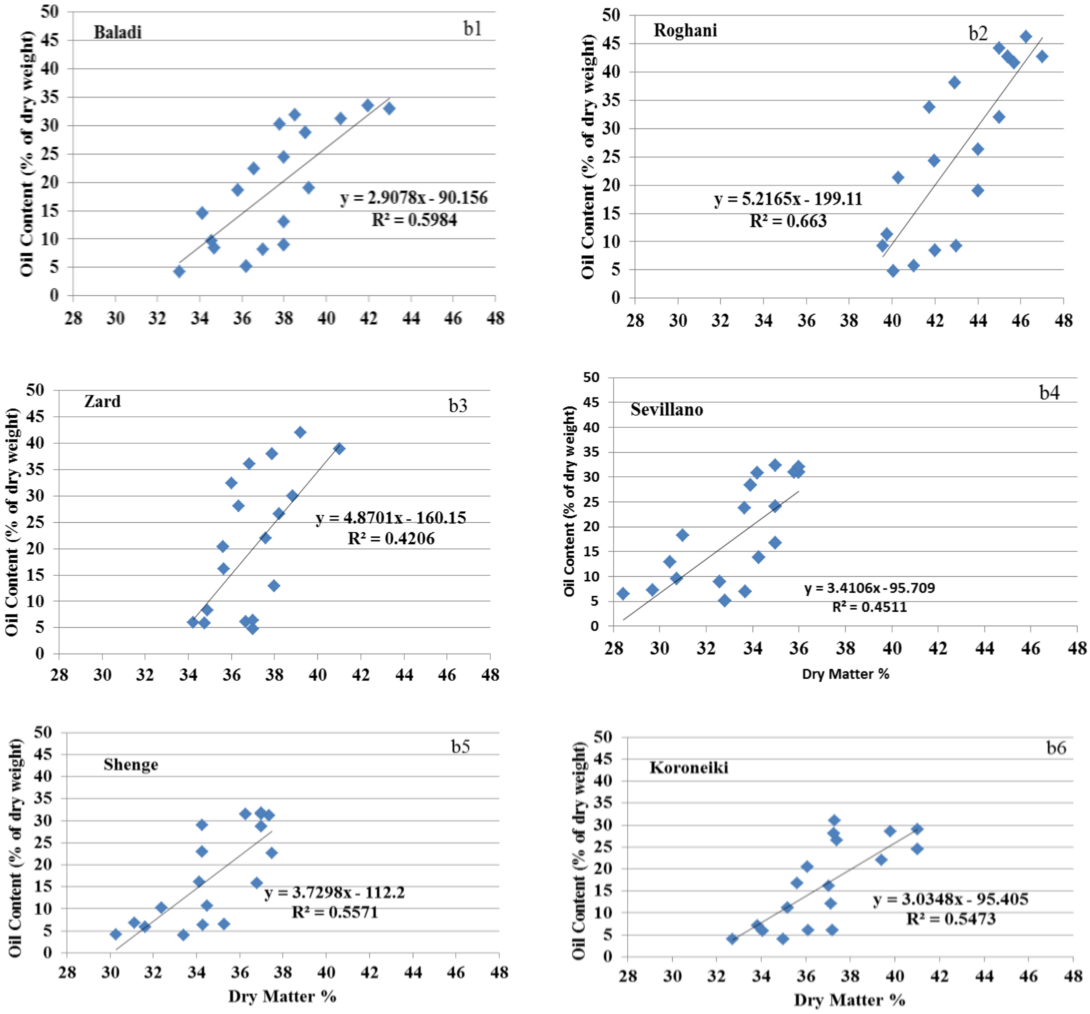

Figure 1. Relationship between oil content (dry weight basis) and fruit dry matter during three successive years 2007, 2008 and 2009 in different cultivars

Ajamgard & Zeinanloo (2013) compared quantitative and qualitative yield of 21 Olive Cultivars in North of Khuzestan Province, Iran. They observed that only S-X variety had about 18% oil in fresh matter and other varieties had less olive oil because of warm environmental condition. Arji & Norizadeh (2015) reported that oil content was strongly related to environmental conditions. They recorded higher oil content (>48% based on dry matter) for 6 olive cultivars (Konservolia, Agouromanako, Patrini, Thiaki, Chalkidikis and Megaron) in Taroum region with longitude: 50º 49´ E, latitude: 47º 36´ N, altitude: 300 m and 17.6^{o}c annul mean temperature in north part of Iran which can be compared with SarpoleZehab region with longitude: 45º 51´ E, latitude: 34º 30´ N, altitude: 570 m and 20.1^{o}c annul mean temperature in west part of Iran (<35% for all cultivars).

The olive oil accumulation results from a multivariate interaction in which genotype, environment, and agronomic-dependent factors are involved. The genotype controls genetic traits accounting for the rate and pattern of fruit growth, oil accumulation and fruit ripening, while the genotype × environment interaction changes the rate of fruit growth, oil accumulation and fruit ripening pattern (Arji, 2015). Cimato *et al.*, (2001) stated that olive trees need specific temperature patterns for optimal growth which are known empirically by the growers.The optimal temperature is 25-28°C for photosynthesis and growth during summer and autumn. When temperature increases more than this, photosynthesis and other physiological phenomena are reduced; then, carbohydrate and oil accumulation reduction take place. In this experiment, for three successive years, maximum and mean temperatures were higher than 40 and 30^{o}C during Jun, July and August respectively (Table 1). This high temperature coinciding with low relative humidity (Table 2) had negative impact on oil accumulation in such environmental conditions. Low oil percentage in all cultivars strongly depends on environmental conditions, especially temperature.

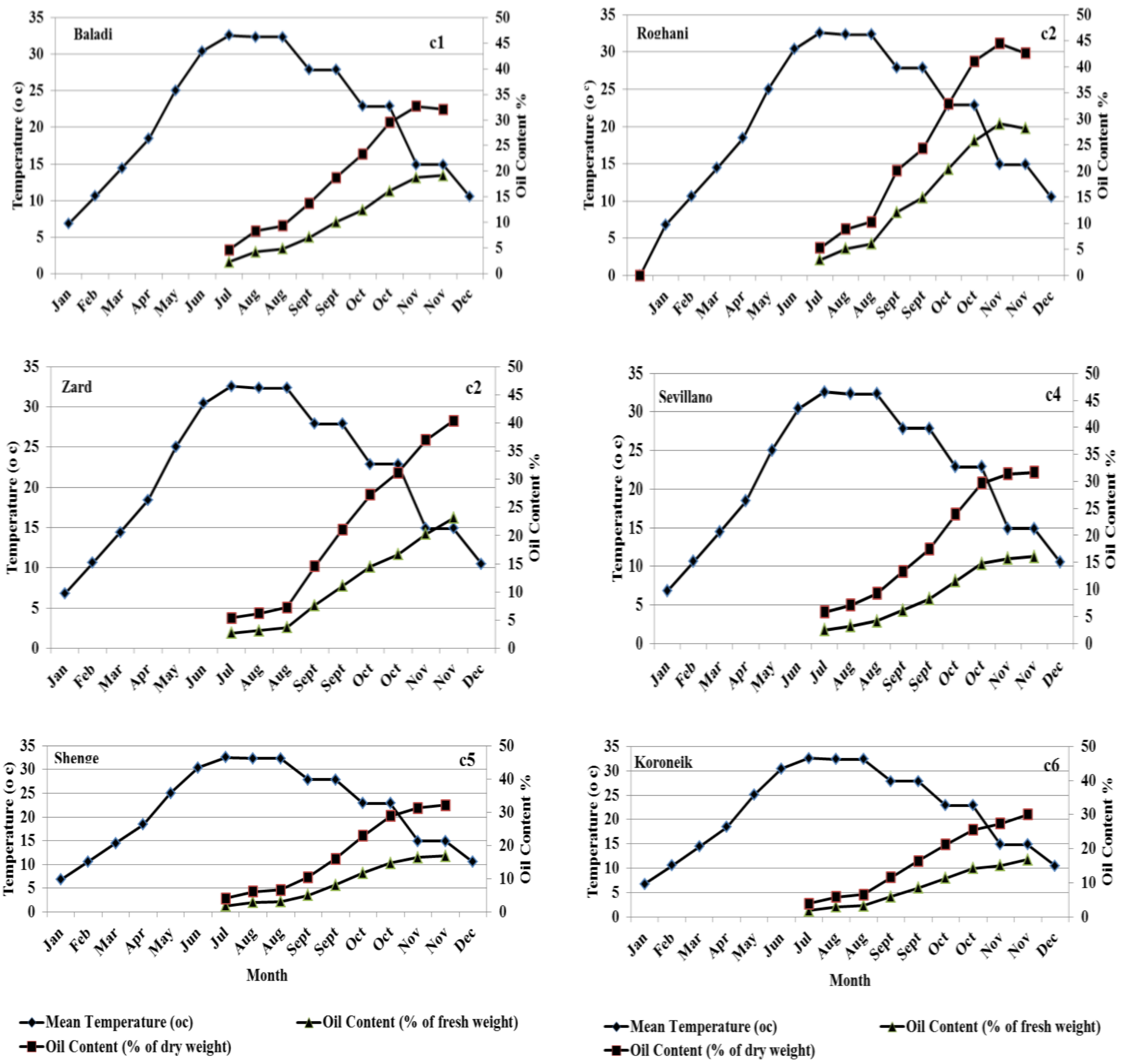

Figure 2. Olive oil accumulation based on fresh and dry weight in relation to mean temperature during three successive years 2007, 2008 and 2009 in different cultivars.

The climate in Sarpole Zehab is characterized by long, very hot and dry summer and moderate winter. The weather condition data, presented in tables 1 and 2, were recorded in Sarpole Zehab synoptic weather station. July and August were the hottest months; with average temperature of above 32^{o}c. Monthly average maximum temperature during flowering and fruit set in April and May were 26.13 and 34^{o}c, respectively. The occurrence of high temperature (July–August) was harmful for oil accumulation. Warm night temperature can cause damage to fruit growth, carbohydrate accumulation and subsequent oil formation due to respiration.

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