Performance and Water Requirement of Young Olives (*Olea europaea* L.) Under the Harsh Environment of Kuwait

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Abstract

In Kuwait, plants are frequently exposed to high temperatures, low relative humidity and drought. As water resources available for agriculture are limited, an efficient irrigation strategy is vital for sustainable olive production. In view of these facts, an irrigation study comprising five cultivars (Arbequina, Barnea, Coratina, Koroneiki and UC13A6) and three levels of irrigation (50, 75 or 100% of ETc) was conducted using brackish water with 5.0 dS. m^{-1} ECe. All five cultivars showed excellent adaptation to harsh weather conditions of Kuwait and brackish water irrigation. Vegetative growth in these cultivars was not significantly affected when the quantity of the irrigation water was reduced to 50% of ETc, indicating that these cultivars were able to tolerate severe and prolonged drought conditions. However, cultivar differences in respect of adaptation to harsh weather were significant at $p \leq 0.01$. Overall, cultivars Barnea and Arbequina exhibited better adaptability than other cultivars to harsh environmental conditions of Kuwait and produced growth rates in excess of 50% during the initial 18 mo. after planting even when the quantity of irrigation water was reduced to 50% of actual ETc. UC13A6 was affected the most by the harsh growing conditions of Kuwait.

1. Introduction

Kuwait is a small, flat to gently undulating desert country extending between latitudes 28^0 33' and 30^0 05' N and longitudes 46^0 33' and 48^0 30' E in the north-eastern part of the Arabian Peninsula. The climate is classified as hyperarid (precipitation / potential evapotranspiration = < 0.05) and is characterized by extremely hot dry summers with long, intense sunshine hours and moderately cool short winters with occasional rain (Middleton and Thomas, 1997). The average daily maximum and minimum temperatures varies between 18.9^0C during January and 46.8^0C in July and between 8.2^0C during January and 28.3^0C during July (Annual Statistical Report, 2006). The rainfall which occurs anytime between mid October and late April, is minimal; averaging about 115 $mm.y^{-1}$ (fluctuates between 25 and 250 mm), but the evaporation is very high, ranging from 3.1 to 21.6 $mm.d^{-1}$. The relative humidity is low, and strong, dry and hot northwesterly winds prevail during summer, particularly in June and July. The desalinated sea water, the main source of fresh water in Kuwait and brackish underground water are for irrigation.

Environmental adaptability and tolerance of olives to prolonged drought and enhanced salinity conditions made it possible to grow them in several Mediterranean countries, such as Tunisia, Egypt, Morocco and Israel where plants are frequently exposed to drought. Previous studies conducted at the Kuwait Institute for Scientific Research (KISR) showed olive to be one of the only few species that can adapt very well to the harsh environment and sandy soils of Kuwait (Bhat, 2002). Furthermore, due to that fact that olive products such as table olive and olive oil are essential part of Arab diet and can be a potential plant for greenery and landscape applications, efforts are afoot at KISR to develop sustainable olive growing in Kuwait.

In Kuwait, irrigation is essential for any viable commercial plant production activity. Because of limited supply of good quality water for irrigation in Kuwait, deficit irrigation at selected phenological stages may be a favored option to optimize economic gains and minimize environmental damage. However, it is important to recognize the fact that plants are exposed to several environmental constraints, such as high light intensity, extreme temperatures, very low relative humidity, strong winds, dust storms and progressive salinization of soil under irrigation. Under these conditions, a sound, efficient irrigation strategy where irrigation amount is based on the plant's actual need at different phenological stages and under fluctuating environmental conditions is needed.

In perennial fruit crops, such as olive, mild water stress or deficit irrigation has been found to have positive response on vegetative growth and yield (Goldhamer, et al., 1994; Tognetti, et al., 2006; Perez-Lopez, et al., 2007). Although olive tree is known for its adaptation to severe and prolonged water stress (Giorio et al, 1999; Sofo et al., 2004; Connor and Fereres, 2005), water deficit affects active growth, fruit development and product quality (Chartzoulakis et al., 1992; Wahbi et al., 2005, Gomez-Rico et al, 2007). Response of olive plants to drought has been shown to be cultivar-specific and influenced by the stage of development, severity of drought and agronomic practices (Dettori et al., 1989; Patumi et al., 1999; 2002; Motilva et al., 2000; Mangliulo et al., 2003; Boussadia, et al., 2008; Gomez-Rico et al., 2007; Moriana et al., 2007). In view of this, studies reported here were conducted during 2006-2008 to determine the water requirement of young plants of five olive cultivars under the harsh environmental conditions of Kuwait.

2. Materials and Methods

2.1. Climatic conditions

The weather data for daily minimum and maximum temperature, minimum and maximum relative humidity and rainfall were obtained from the nearby KISR weather station and monthly averages were calculated. The weather during the study period (October 2006 – August 2008) was harsh and fluctuated considerably, with the monthly maximum and minimum temperatures ranging between 52.0^0C in August, 2008 and 2.54^0C in January 2007, and between 2.01^0C in January 2008 and 33.0 in August 2008, respectively (Fig. 1). During this period, a total of 130.5 mm rainfall was received (84 mm during October 2006 – September 2007 and 46.5 mm during October 2007 – August 2006 year as against the thirty year average of 110 mm. yr^{-1}). The daily average minimum and maximum relative humidity during this period ranged between 31.49% in May 2007 and 92.1% in January 2007. The dust storms were also unusually severe and more frequent than normal.

2.2. Study site

The soil in the experimental site is predominately sandy with an average pH and ECe values of 7.33 and 6.88 dS. m^{-1}, respectively. The soil contained very little in organic matter, 3.36 mM Ca^{+2}, 0.94 mM Mg^{+2}, 0. 23 mM K^+, 8.7 mM Na^+, and 5.29 mM Cl^-. It had poor water retention capacity (Bhat et al., 2008a). The irrigation water used in the study was brackish with pH of 7.64, electrical conductivity around 5.0 dS. m^{-1} and SAR of 8.01.

2.2. Plant material and Planting

One-year old grafted five cultivars, Barnea, Coratina, Arbequina, Koroneiki and UC13A6 obtained from Australia were used for this study. These cultivars were selected based on the published reports on their adaptability to harsh environmental conditions and degree of tolerance to drought and soil salinity. Efforts were made to include cultivars with diverse origin to ensure good field establishment and adaptation to pedoclimatic conditions of Kuwait. These plants were acclimatized to prevailing weather conditions for eight months and planted in the field in the third week of October 2006. For planting, 50-cm diameter planting holes were dug and backfilled with a soil mixture containing equal proportions by volume of sandy loam soil and sphagnum peat moss. After planting, plants were allowed to fully establish in the field before initiating irrigation treatments. During the initial establishment period, a uniform nonlimiting irrigation regime using fresh water (ECe = 1.0 dS. m^{-1}) was used to secure good plant establishment.

Trees were trained with a one main stem up to height of about 50 cm from the gerund after which two stems were allowed to develop. Minimal pruning was practiced to develop desired tree shape and canopy.

2.3. Treatment Details

The 100% irrigation levels shown in Table 1 were calculated based on the results of earlier studies (Suleiman, et al., 2004; Bhat et al., 1999). Three irrigation levels (50, 75, 100 % crop evapotranspiration rates) were tested in each of the five cultivars. Any rainfall received during the week was adjusted in the ensuing week. A timer (Rainbird, USA) and a portable water meter were used to measure the amount of water applied to each treatment. The total amount of water applied in the three irrigation treatments were 11,770, 8,863 and 5,995 liters per plant, respectively.

2.4. Experimental design, data recording and statistical analysis

A complete randomized block design with three irrigation levels, five cultivars, and three replications with three plants of each cultivar per treatment (a total of 135 plants) was used to assess the growth response of olive plants to different irrigation levels. Data on plant height, stem diameter (dia.) and number of branches per plant were recorded at bimonthly intervals, whereas the shoot length, leaf area, petiole length, chlorophyll index and weight of pruned material was recorded after 14 months (mo.) of initiation of the irrigation treatments.

Data were analyzed for ANOVA using the ‘R’ procedure (Crowley, 1985) and the least significant difference was calculated using the Little and Hill (1978) procedures.

3. Results

The periodic data on average relative growth rate in plant height, stem dia. and number of branches are presented in Table 2.

3.1. Response to harsh environment

All five cultivars exhibited good adaptation to the prevailing extreme temperatures and low relative humidity conditions of Kuwait and brackish water irrigation. Under nonlimiting moisture regime (100% ETc), the height growth of Barnea (relative growth rate (RGR) = 89.7% in 19 mo.) and Arbequina (RGR = 73.2%) were significantly better than that of other cultivars. Coratina was the next best cultivar with respect to adaptation to the harsh weather conditions. In contrast, UC13A6 plants, although survived the harsh weather conditions, exhibited negative growth rates. The growth of plants in all cultivars slowed down during summer months, but the normal growth was resumed with the return of moderate weather conditions.

3.2. Physical plant condition

Except for UC13A6, plants produced normal growth and did not show any shoot injury under Kuwait’s environment and brackish water irrigation. Barnea plants, in general, appeared more vigorous than others in all irrigation treatments. Irrespective of irrigation treatments, leaves in UC13A6 were chlorotic, crinkled and smaller especially during summer months. Because of shorter branches and fewer number of leaves produced on each branch, UC13A6 had lowest canopy density of all cultivars.

3.3. Plant Height

During the first 18 mo. from the start of the irrigation treatments, the growth rate of various cultivars ranged from 18.6 (UC13A6) to 89.7 % (Barnea) in 100% ETp; 27.6

(UC13A6) to 79.8.% (Arbequina) in 75% ETp treatment; and 4.8 (UC13A6) to 76.2% (Barnea) in the 50% ETp treatment (Table 2; Fig 2). The performance of UC13A6 was significantly poor at all irrigation levels. However, irrigation levels did not appear to have any significant influence in all cultivars.

3.4. Stem Diameter

The average stem diameter after 18 mo. of start of the irrigation treatments ranged from 21.3 (UC13A6) to 54.6 mm (Barnea) in the 100% ETp treatment; 24.6 (UC13A6) to 53.0 mm (Barnea) in the 75% ETp treatment; and 17.1 (UC13A6) to 52.7 mm (Barnea) in the 50% ETp treatment (Table 2). While the differences among varieties were significant at $p \leq 0.01$, irrigation levels did not seem to have any influence on stem dia.

3.5. Number of Branches

The average number branches produced by plants under various treatments ranged from 21.1 (UC13A6) to 32.0 (Koroneiki) in the 100% ETp treatment; 26.7 (UC13A6) to 32.8 (Koroneiki) in the 75% ETp treatment; and 20.8 (UC13A6) to 32.4 (Barnea) in the 50% ETp treatment (Table 2). Significantly fewer branches were produced by the cultivar UC13A6 than other cultivars.

3.6. Time of Resprouting, Rate of Growth, Number of Nodes and Intenodal length of New Shoots

The plants remained more or less dormant during summer months and resumed normal growth in September when the weather turned moderat (Fig. 1). The average length of new shoots ranged from 14.7 (UC13A6) to 32.9 cm (Koroneiki) in the 100% ETp treatment; 11.9 (UC13A6) to 36 cm (Coratina and Koroneiki) in the 75% ETp treatment; and 11.3 (UC13A6) to 33.4 cm (Coratina) in the 50% ETp treatment (Table 3). The average number of nodes on the new shoots ranged from 8.3 (UC13A6) to 13.4 (Arbequina) in 100% ETp treatment; 9.2 (UC13A6) to 13.4 (Koroneiki) in 75% ETp treatment; and 8.6 (UC13A6) to 14.4 (Arbequina) in the 50% ETp treatment (Table 3). Irrespective of the treatment, the internodal length, in absolute terms, was the lowest in

UC13A6 and the highest in Coratina; however, water stress did not seem to have any influence on the internodal length.

3.7. Leaf area and chlorophyll index and petiole length

The irrigation treatments did not have significant effects on the leaf area and petiole length, but reduced the leaf chlorophyll contents (Table 4).

3.8. Weight of pruned material

The weight of pruned materials after 14 mo. of start of the irrigation treatments was the highest in Barnea plants that were irrigated at 100% ETp and lowest in UC13A6 plants that were irrigated at 50% ETp (Table 4).

4. Discussion

Although the weather conditions during six – eight mo. in a year were less conducive (the maximum daytime temperatures 35^0C and minimum relative humidity of less than 10%) to normal plant growth, some of the cultivars produced growth rates in excess of 50% in 14 mo., which compare well with those reported for young trees under the Mediterranean climates where favorable weather persists for most part of the year. During this period, plants were exposed to frequent dust storms and airborne salts brought from the nearby sea by strong winds during summer months. Furthermore, irrigation with brackish water also imposes severe restriction of plant growth, especially under harsh weather conditions (Bhat et al., 2008b). These observations clearly demonstrate the ability of these cultivars to adapt to harsh weather conditions of Kuwait and brackish water irrigation (ECe of 5.0 dS. m^{-1}). As is expected, cultivars differed in their response to the prevailing weather conditions, with Barnea, Arbequina and Coratina showing the significantly greater adaptation than UC13A6. Besides adversely affecting the vegetative growth, high temperatures reduced the number and size of leaves and caused chlorosis (lower chlorophyll index) and crinkling of individual leaf in UC13A6. The foliage density was also low in these plants. These observations highlight the importance of cultivar selection for commercial olive growing in Kuwait.

In the present study, the vegetative growth was not adversely affected when the quantity of water applied through irrigation was reduced to 50% of daily ETc. This is indicative of the ability of these cultivars to adapt themselves to reduced irrigation water volumes. The differences might be related to the inherent ability of these cultivars to acclimatize to amount of water available in the root zone, which may take varying length of time. Several researchers have found that the acclimatization of olive trees to drought was associated with changes in the leaf at morphological, anatomical and physiological levels, which takes some time. Olive trees adapted to drought and other prevailing conditions reveal enhanced sclerophylly with high density of the foliar tissues and the presence of thick cuticle and trichome layers (Bacelar et al., 2004; 2006). Drought stress was shown to reduce the size of epidermal and mesophyll cells with a parallel increase in cell density, increase the density of stomata and nonglandular hairs and decrease the size of individual stomata (Bosabalidis and Kofidis, 2002; Fernandez et al., 1997). A number of researchers also observed low water availability to affect growth and biomass accumulation, reduce leaf area leading to shedding of older leaves (Bacelar et al., 2007), reduce leaf water potential (Wahbi et al., 2005; Kasraoui et al., 2006; Giorio et al., 1999), reduce stomatal conductance (Giorio et al., 1999; Ben Ahmed et al, 2007; Bacelar et al., 2006; 2007) and lower photosynthetic activity and transpiration rates (Nogues and Baker, 2000). Dichio et al., 2003 and Santos et al., 2007 reported that the osmotic adjustment of olive trees leads to a large amount of water being extracted from the soil, which may reduce the effect of irrigation in low-density olive orchards. The results of our study and those reported previously by other researchers suggest significant cultivar differences in water utilization and adaptation to the prevailing environmental conditions. Hence, it is imperative that cultivar-specific irrigation scheduling should be developed based on the prevailing environmental conditions. Other management practices such as pruning and training, use of hydrophilic polymers and mulches and fertilizer applications must be tailored based on both the quality and amount of irrigation water available.

5. Conclusions

The five cultivars tested in this study, namely Arbequina, Barnea, Coratina, Koroneiki and UC13A6, were able to adapt to the harsh weather conditions of Kuwait and brackish water irrigation, although significant cultivar differences were clearly evident. These results highlight the good prospects for growing olives as a commercial crop in Kuwait. The fact that a reduction in the volume of irrigation water by as much as 50% did not adversely affect vegetative growth during the initial stages of development in these cultivars points to vast opportunities that exist for improving water-use-efficiency and reducing dependence on expensive fresh water supplies in olive production and greenery development in the country. Cultivars, Barnea, Arbequina and Coratina were more vigorous than others throughout the duration of the study, whereas UC13A6 exhibited reduced growth and foliar injury particularly during the summer months, thereby stressing the importance of careful cultivar selection in commercial olive growing. The study is being continued to ascertain the optimum water requirement during bearing and no-bearing growth stages of these varieties.

Acknowledgement

Authors would like to thank the Kuwait Foundation for the Advancement of Sciences and the management of the Kuwait Institute for Scientific Research for their continued interest, encouragement and financial support to the project. The assistance provided by all project staff and other Aridland Agricultural Department staff in carrying out various project assignments is also gratefully acknowledged.

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Table 1. Volume of Water Applied in the 100 ETp Irrigation Treatment

	Amount (mm) of Water Applied/ Plant/ Day	
Month	**First Year**	**Second Year**
January	2.3	2.3
February	3.2	3.2
March	5.1	5,1
April	5.4	5.6
May	7.4	7.4
June	7.4	7.4
July	7.4	11.6
August	7.4	11.6
September	5.6	9.4
November	3.8	6.4
December	2.3	2.8

Table 2. Relative growth rate of olive cultivars in different irrigation treatments

Cultivars	% of ETp	Relative growth rate Height (%)		Stem diameter (mm)		Number of branches	
		12 mo	18 mo	12 mo	18 mo	12 mo	18 mo[b]
Arbequina	100	46.3	73.17	25.7	36.4	39.9	30.0
	75	44.1	79.75	25.9	36.6	39.7	32.4
	50	36.2	64.23	23.8	31.0	36.7	28.1
Barnea	100	47.9	89.71	38.6	54.6	36.0	30.1
	75	48.2	74.69	36.2	53.0	43.2	32.2
	50	45.3	76.16	37.2	52.7	43.4	32.4
Coratina	100	34.5	59.10	33.4	49.7	30.0	24.6
	75	48.7	59.19	33.0	46.2	29.9	22.1
	50	44.0	73.34	30.4	41.1	28.0	23.7
Koroneiki	100	14.7	49.29	28.0	40.7	39.6	32.0
	75	15.2	38.51	30.6	41.6	40.2	32.8
	50	20.3	39.73	28.6	40.4	41.2	31.1
UC13A6	100	-11.1	18.57	11.6	21.3	16.4	21.1
	75	1.7	27.59	13.3	24.6	16.1	26.7
	50	-15.6	4.78	11.6	17.1	15.2	20.8
Significance[a] - Variety		***	***	***	***	***	***
LSD $_{0.05}$ - Variety		7.93	11.48	2.18	2.62	3.96	2.83
Significance - Irrigation		ns	Ns	ns	ns	ns	Ns

[a] "***", "*" denotes that treatment means are significant at $p \leq 0.01$ and $p \leq 0.001$, respectively; ns = treatment means are not significantly different at $p \leq 0.05$.
[b] Plants were pruned in November to improve light penetration.

Table 3. Average Shoot length, Internodal Number and Internodal Length of Olive Cultivars in Different Irrigation Treatments

Cultivar	Treatment (% ETp)	Average shoot length (cm)	Number of nodes	Internodal length (cm)	Pruned weight Kg. plant^{-1}
Arbequina	100	24.5	13.4	1.8	3.11
	75	27.1	13.2	2.1	2.73
	50	28.1	14.4	2.0	1.55
Barnea	100	27.1	11.3	2.4	4.33
	75	33.9	12.1	2.8	3.84
	50	32.4	12.2	2.6	4.06
Coratina	100	30.8	10.3	3.0	4.68
	75	36.9	11.4	3.3	3.85
	50	33.4	10.7	3.2	2.99
Koroneiki	100	32.9	13.0	2.5	2.82
	75	36.0	13.4	2.7	3.08
	50	31.1	12.6	2.5	2.60
UC13A6	100	14.7	8.3	1.7	0.33
	75	11.9	9.2	1.3	0.45
	50	11.3	8.6	1.2	0.23
Significance – Cultivar[a]		ns	ns	ns	***
LSD at $p \leq 0.05$					1.90
Significance – Irrigation		ns	ns	ns	ns

[a] ns = Treatment means are statistically not different at $p \leq 0.05$; *** = significant at $p \leq 0.001$.

Table 4. Average Leaf Area, Chlorophyll Index and Petiole Length of Olive Cultivars in Different Irrigation Treatments

Cultivar	Treatment (% ETp)	Average leaf area (cm^2)	Chlorophyll index	Petiole length (cm)
Arbequina	100	3.7	56.4	5.1
	75	5.2	71.0	5.1
	50	4.6	60.4	4.1
Barnea	100	4.3	66.5	3.1
	75	5.2	65.3	3.6
	50	5.7	34.4	5.2
Coratina	100	5.5	74.2	3.3
	75	9.0	86.9	4.2
	50	7.5	53.2	4.4
Koroneiki	100	2.6	69.4	2.6
	75	3.5	37.7	3.3
	50	2.6	40.8	3.2
UC13A6	100	2.6	88.9	2.8
	75	2.8	60.5	2.1
	50	4.7	47.1	4.0
Significance (Irrigation treatments) [a]		ns	ns	ns
Significance (Cultivars)		ns	ns	ns

[a] ns = Treatment means are statistically not different at $p \leq 0.05$.

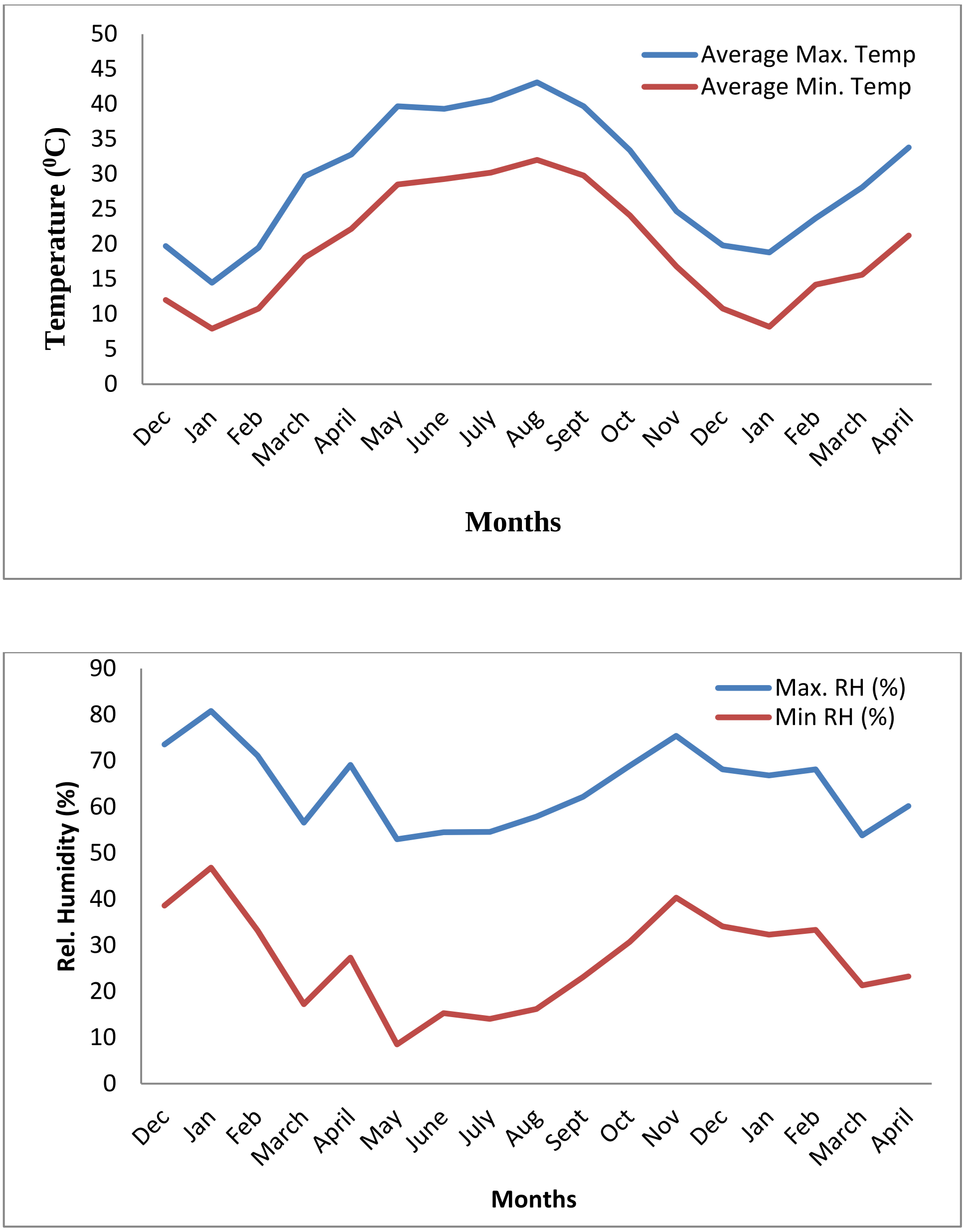

Fig. 1. Average monthly maximum and minimum temperatures and relative humidity during the December 2007 to April 2009.

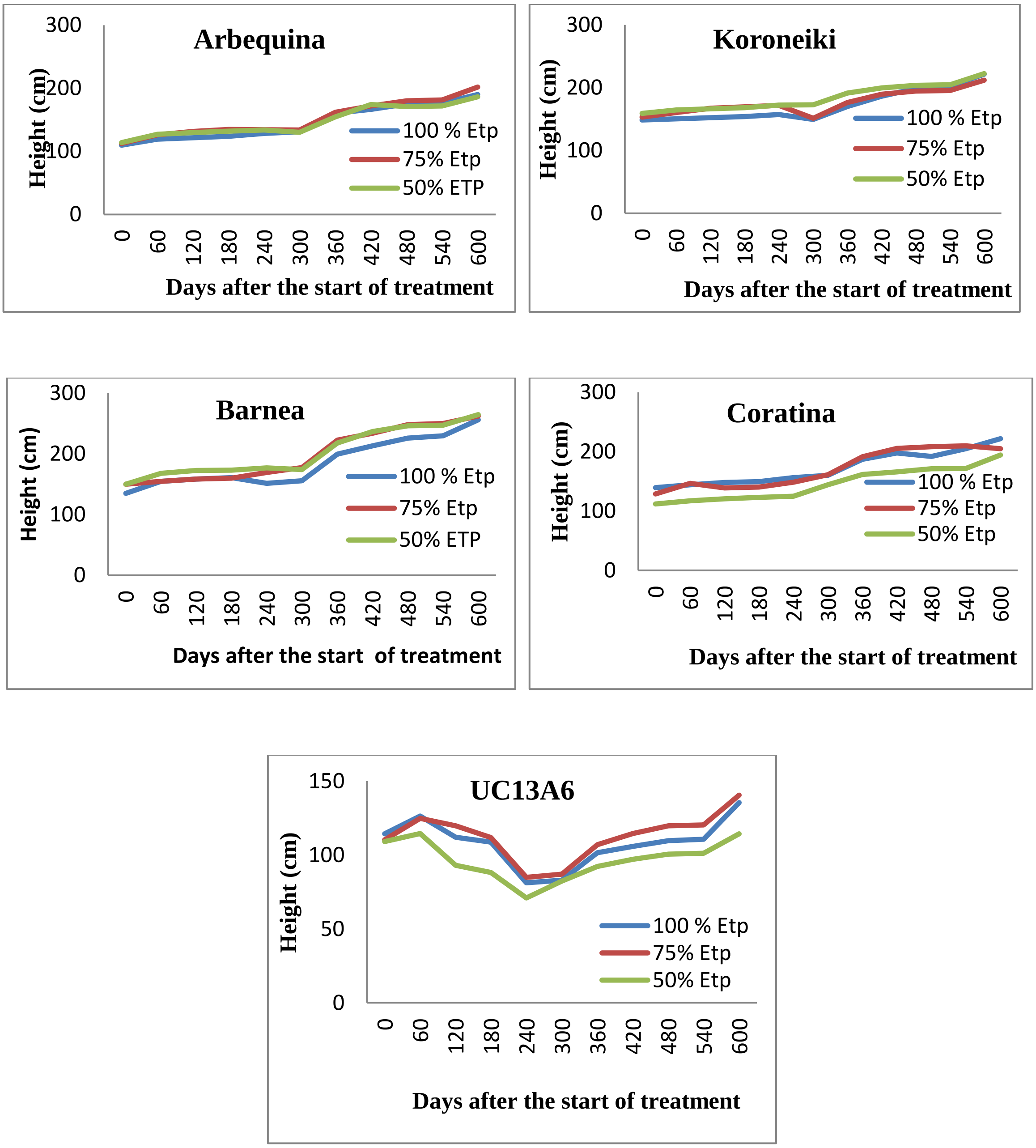

Fig. 2. Periodic plant height of five olive cultivars under Kuwait’s environment.

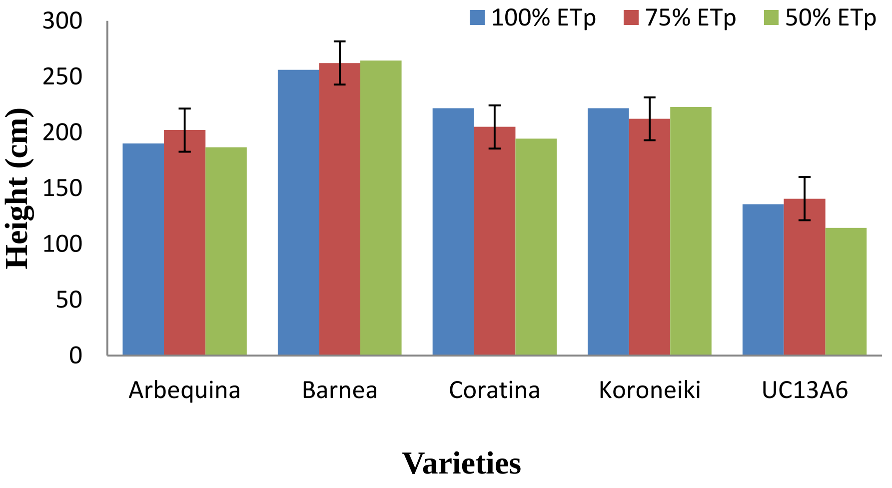

Figure 3. Plant height at 18 mo. after the start of the irrigation treatments.