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RELATIONSHIP BETWEEN VEGETATIVE GROWTH AND NUT CHARACTERISTICS IN ALTERNATE BEARING PISTACHIO (*PISTACIA VERA*) CULTIVARS EXPOSED TO DROUGHT

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Abstract

Among abiotic stress factors, drought stress is of the most influential factors limiting plant growth and impairing plant metabolism. In addition to the abiotic stress factors, alternate bearing is a main physiological problem for horticultural plants including olive, pistachio, hazelnut and apple. In this context, a 3-year field study was designed for three pistachio cultivars, namely 'Uzun', 'Siirt' and 'Ohaidi'. The cultivars were exposed to irrigated and non-irrigated conditions. After experimental period, yield, shoot length and nut characteristics were measured. According to years, shoot length, 100 nut weight, nut internal weight, nut length, nut width and nut thickness decreased but blank nut ratio increased in productive year as a yield. Regarding with varieties, there was no significant difference yield, blank nut, and split nuts among cultivars but shoot length, nut width and thickness were higher in 'Ohaidi' cultivar. Lowest 100 nut weight and nut internal weight were determined in 'Uzun' cultivar and highest nut length was observed in 'Siirt' cultivar. Irrigation only affected the shoot length from given properties. As a result, yield of the tree affected vegetative development and nut characteristics. Along with this study, finally vegetative growth and fruit characteristics were correlated.

Key words*: alternate bearing, pistachio cultivars, Pistacia vera, vegetative growth, nut characteristics.*

INTRODUCTION

Turkey has an important place in the world with its unique ecological conditions and is the gene center of pistachio and pistachio production, spreading in the south-eastern parts of Turkey. The irregular fruiting behaviour (alternate bearing) and its effects in yield reduction in pistachio are of the major problems. Alternate bearing is related to many factors mainly classified as intrinsic factors such as endogenous hormones, nutrition, carbohydrate accumulation allocation between reproductive and vegetative organs of the plant, rootstocks, cultivars, genetic factors (Nzima et al., 1997; Spann et al., 2008; Kumar et al., 2016; Goldschmidt and Golomb, 1982; Rosecrance et al., 1998; Durand et al., 2013; Kafkas et al., 2006) and extrinsic such as environmental, climatic and soil properties, climatic changes in rainfall and temperature, compensate chilling and total heat demand of trees, inadequate pollination, traditional cultural practices, fertilization, harvesting, prolonged period of water stress etc. (Elloumi et al., 2013; Acar and Eti, 2007; Khoyerdi et al., 2016; Marcinska et al., 2013; Dag et al., 2009; Kallsen, 2017). Disturbance in adequate and balanced nutrition of the plant lead to low productivity and quality. The alternate bearing is the result of the disruption deviating from optimal nutrition caused by domination of fruit in relation to nutrient use competition between fruit, buds and leaves (Crane and Nelson, 1971). Pistachio is mainly grown under rain fed conditions in the Mediterranean basin and considered as drought and saline-resistant crop (Behboudian et al., 1986; Rieger, 1995). Irrigation is of the essential factor for plant yield. In pistachio, irrigation improves nut quality and reduces the alternate bearing pattern (Kanber et al., 1993).

Plenty of flower buds are formed every year in pistachio that makes it different from other

species showing alternate bearing. However, the flower buds fall off during the summer months.

The alternate bearing in pistachio is the result of flower buds falling off, not concerned with flower bud formation (Crane, 1971).

Of the abiotic stress factors, drought is considered as the most hazardous factors on sustainable agriculture worldwide (Din et al., 2011; Anjum et al., 2012; Lefèvre et al., 2012).

Drought is assumed to be the consequences of soil and/or atmospheric water deficit, causing substantial eco-physiological constraints to plant survival and to crop productivity and quality (Boyer, 1982).

Drought associated studies are great concern of the plant scientists for developing, improving or exploring the drought-tolerant plant species (Hamrouni et al., 2001; Al-Barrak, 2006; Bettaieb et al., 2009; Bybordi, 2010).

In the current study, it was aimed to reveal the relationship between yield and vegetative growth and nut characteristics in pistachio cultivars bearing alternatively in response to the irrigated and non-irrigated conditions.

MATERIALS AND METHODS

Experimental Material

The research was carried on 25 years old cultivars 'Siirt', 'Uzun' and 'Ohaidi' grafted onto a *Pistacia vera* rootstocks which were cultivated in 7 x 2 m intervals at Pistachio Research Institute.

The experiments were designed under irrigated and non-irrigated conditions according to the randomized plot design with four replicates.

Yield, vegetative growth and nut characteristics

Yield (kg/tree) was obtained by dividing the total harvested product per tree for each variety.

Shoot length (SL) was found by measuring the shoots at the end of vegetation. Counts and measurements of the fruits in the clusters were made for the fruit characteristics. Nut length (NL), nut width (NW), nut thickness (NT), nut weight (100-NW), internal nut weight (INW), shelling percentage (SP) and blank nut (BN) are also evaluated for the fruit characteristics.

Statistical analysis:

SPSS statistical program was used to determine statistical significance levels by employing the independent one-way ANOVA followed by Duncan multiple range test and the differences between individual averages were considered to be statistically important at $p< 0.05$. The results were expressed as mean.

RESULTS AND DISCUSSIONS

The yield, vegetative growth and nut characteristics values of 'Uzun', 'Siirt' and 'Ohaidi' pistachio varieties were measured for three years on irrigated and non-irrigated conditions and the inter-parameter relationships were determined by statistically evaluating the changes between parameters according to years, irrigation and varieties. The obtained values and changes are shown in Table 1. Changes in yield, growth and nut characteristics' parameters according to irrigation, cultivars and years are represented in Table 2. Accordingly, irrigation increased shoot length. Of the varieties, 'Ohaidi' with more shoot, 'Siirt' and 'Ohaidi' with more 100-nut weight and internal nut weight, 'Siirt' with broader nut and 'Ohaidi' with thicker nuts were of the results of the present study.

When differences between the years were investigated, the yields of the following years were about the same, while the first year received more yield than the other years. During the year with fewer yields, higher shoot length and lower blank nut, 100-nut weight, internal nut weight, split nut, nut length, width and thickness were obtained.

Changes and correlations between the yield, shoot growth and nut characteristics under irrigated and non-irrigated conditions for 'Uzun' cultivar are shown Table 3 and Figure 1. In terms of correlation coefficient (r) values there were negative correlation between yield and blank nut under non-irrigated (-0.811) condition, yield and 100-nut weight under irrigated (-0.844), yield and shelling percentages under irrigated (-0.888) condition, yield and nut width under non-irrigated (-0.807) condition, yield and nut thickness under irrigated (-0.974) and non-irrigated (-0.979)

Table 1: Growth and nut characteristics' parameters under irrigated and non-irrigated conditions for pistachio cultivars

		'UZUN'			'SIIRT'			'OHAIDI'		
		1.Year	2.Year	3.Year	1.Year	2.Year	3.Year	1.Year	2.Year	3.Year
Yield (kg/tree)	IR	4.6	2.9	3.3	5.6	3.7	3.8	4.5	3.1	4.8
	N-IR	6.4	3.2	5.1	7.7	3.7	3.6	6.4	2.8	4.3
	AVE	5.49	3.05	4.20	6.65	3.68	3.71	5.44	2.93	4.58
Shoot lenght (cm)	IR	12.8	13.0	21.5	16.6	18.6	22.5	25.0	25.9	32.0
	N-IR	13.0	14.3	19.8	13.8	13.1	21.2	21.5	24.1	27.9
	AVE	12.90	13.65	20.65	15.20	15.85	21.85	23.25	25.00	29.95
Blank Nut (%)	IR	17.7	15.7	9.2	22.9	9.7	8.0	18.1	10.9	7.1
	N-IR	14.0	22.2	11.7	25.4	17.8	11.2	40.1	14.6	9.7
	AVE	15.85	18.95	10.45	24.15	13.75	9.60	29.10	12.75	8.40
Nut weight (g/100 nut)	IR	168.5	181.2	187.7	187.0	249.7	252.3	198.4	244.6	249.9
	N-IR	165.1	183.4	185.5	179.2	245.3	246.0	220.6	243.9	246.9
	AVE	166.8	182.3	186.6	183.1	247.5	249.2	209.5	244.3	248.4
Internal nut weight (g/100 nut)	IR	59.0	56.0	61.6	69.7	92.3	94.4	81.0	91.1	95.2
	N-IR	61.4	56.9	59.6	74.4	88.8	89.7	90.6	93.5	93.2
	AVE	60.20	56.45	60.60	72.05	90.55	92.05	85.80	92.30	94.20
Shelling (%)	IR	30.0	51.5	59.0	36.0	68.5	80.0	26.0	76.5	77.0
	N-IR	57.5	56.0	61.5	32.5	65.0	75.0	30.0	43.5	74.0
	AVE	43.75	53.75	60.25	34.25	66.75	77.50	28.00	60.00	75.50
Nut lenght (mm)	IR	25.0	25.5	26.1	24.5	27.0	27.4	23.0	23.8	23.0
	N-IR	24.5	25.0	26.1	26.0	26.5	27.4	23.0	23.8	22.5
	AVE	24.75	25.25	26.10	25.25	26.75	27.40	23.00	23.80	22.75
Nut width (mm)	IR	13.5	13.5	14.0	14.2	15.1	15.0	14.5	15.0	15.5
	N-IR	13.0	13.5	13.5	14.2	15.1	14.5	15.0	14.5	15.0
	AVE	13.25	13.50	13.75	14.20	15.10	14.75	14.75	14.75	15.25
Nut thickness (mm)	IR	12.1	13.0	13.0	13.0	14.3	14.2	15.3	15.0	15.0
	N-IR	12.1	13.0	12.5	13.5	14.3	14.2	15.3	14.5	14.5
	AVE	12.10	13.00	12.75	13.25	14.30	14.20	15.30	14.75	14.75

Table 2: Changes in yield, growth and nut characteristics' parameters according to irrigation, cultivars and years

		Yield kg/tree	Shoot length (cm)	Blank Nut (%)	Nut weight (g/100 nut)	Internal nut weight (g/100 nut)	Shelling (%)	Nut length (mm)	Nut width (mm)	Nut thickness (mm)
IRRIGATION	IR	4	20.8 a	13.2	213.3	78.2	56.1	24.8	14.4	13.6
	N-IR	4.8	18.7 b	18.6	212.9	78.0	55.0	24.6	14.2	13.6
CULTIVARS	'UZUN'	4.2	15.6 b	15.1	178.6 b	59.2 c	52.6	25.2 b	13.5 b	12.4 c
	'SIIRT'	4.7	17.6 b	15.8	226.6 a	84.9 b	59.5	26.2 a	14.4 a	13.8 b
	'OHAIDI'	4.3	26.0 a	16.8	234.0 a	90.8 a	54.5	22.8 c	14.9 a	14.7 a
YEARS	1.YEAR	5.9 a	17.1 b	23.0 a	186.5 b	72.7 b	35.3 c	24.2 b	14.0 b	13.3 b
	2.YEAR	3.2 b	18.1 b	15.1 b	224.7 a	79.9 a	60.2 b	25.0 a	14.3 ab	13.8 a
	3.YEAR	4.2 b	24.1 a	9.6 b	228.0 a	82.3 a	71.1 a	24.9 a	14.6 a	13.8 a

condition, positive correlation between yield and internal nut weight under irrigated (0.999) condition. There was no particular correlation between yield and nut length.

Table 3. Correlation coefficient (*r*) values of the growth and developmental parameters under irrigated and non-irrigated conditions for 'Uzun' cultivar

		Y	SH	BN	100-NW	INW	SP	FL	FW
SL	IR	-0.312							
	N-IR	-0.073							
	AVE	-0.136							
BN	IR	0.500	-0.979						
	N-IR	**-0.811**	-0.525						
	AVE	-0.315	**-0.898**						
100-NW	IR	**-0.844**	0.773	-0.887					
	N-IR	**-0.748**	0.716	0.218					
	AVE	**-0.775**	**0.731**	-0.355					
INW	IR	0.565	0.834	-0.703	0.294				
	N-IR	**0.999**	-0.066	-0.815	-0.744				
	AVE	**0.791**	0.500	**-0.830**	-0.226				
SP	IR	**-0.888**	0.714	-0.843	0.996	0.209			
	N-IR	0.366	0.901	-0.842	0.343	0.373			
	AVE	-0.639	**0.849**	**-0.828**	**0.981**	-0.034			
NL	IR	-0.695	0.900	-0.970	0.972	0.510	0.948		
	N-IR	-0.201	0.992	-0.411	0.800	-0.194	0.838		
	AVE	-0.411	**0.959**	**0.736**	**0.894**	0.234	**0.964**		
NW	IR	-0.292	1.000	-0.974	0.760	0.845	0.700	0.891	
	N-IR	**-0.807**	0.648	0.309	0.996	-0.803	0.254	0.741	
	AVE	-0.541	**0.907**	-0.628	**0.951**	0.087	**0.993**	**0.989**	
NT	IR	**-0.974**	0.517	-0.682	0.943	-0.041	0.968	0.839	0.500
	N-IR	**-0.999**	0.117	0.784	0.777	-0.999	-0.325	0.244	0.832
	AVE	**-0.979**	0.333	0.117	**0.887**	-0.651	**0.781**	**0.989**	0.700

Considering average value there were no correlation between yield and shoot length, blank nut, shelling percentage, nut length and nut width but there were correlation 100-nut weight (-0.775), internal nut weight (0.791) and nut thickness (-0.979).

As regards to correlations between each other except yield, correlations were found between shoot length and blank nut (-0.898), 100-nut weight (0.731), shelling (0.849), nut length 0.959) and nut width (0.907), between blank nut and internal nut weight (-0.830), shelling (-0.828) and nut length (0.736), between 100-nut weight and shelling (0.981), nut length (0.894), width (0.951) and thickness (0.887), between shelling percentage and nut length (0.964), width (0.993) and thickness (0.781), between nut length and nut width (0.989) and thickness (0.989), between nut width and nut thickness (0.700).

Changes and correlations between the yield, shoot growth and nut characteristics under irrigated and non-irrigated conditions for "'Siirt'" cultivar are shown Table 4 and Figure 2. Effects of yield on vegetative growth and nut characteristics were more significant in 'Siirt' cultivar than the 'Uzun' and 'Ohaidi' cultivars.

Table 4. Correlation coefficient (*r*) values of the growth and developmental parameters under irrigated and non-irrigated conditions for 'Siirt' cultivar

		Y	SH	BN	100-NW	INW	SP	FL	FW
SL	IR	**-0.729**							
	N-IR	-0.450							
	AVE	-0.568							
BN	IR	**0.989**	-0.824						
	N-IR	**0.895**	-0.801						
	AVE	**0.958**	**-0.779**						
100-NW	IR	**-0.997**	0.782	-0.998					
	N-IR	**-0.999**	0.439	-0.890					
	AVE	**-0.999**	0.593	**-0.967**					
INW	IR	**-0.992**	0.808	-1.000	0.999				
	N-IR	**-0.999**	0.478	-0.909	0.999				
	AVE	**-0.997**	0.629	**-0.977**	**0.999**				
SP	IR	**-0.955**	0.899	-0.989	0.976	0.984			
	N-IR	**-0.979**	0.623	-0.967	0.976	0.985			
	AVE	**-0.969**	**0.754**	**-0.999**	**0.976**	**0.985**			
NL	IR	**-0.985**	0.837	-0.999	0.996	0.999	0.992		
	N-IR	**-0.786**	0,906	-0.979	0.779	0.805	0.896		
	AVE	**-0.953**	**0.790**	**-0.999**	**0.962**	**0.973**	**0.998**		
NW	IR	**-0.999**	0.690	-0.979	0.991	0.984	0.937	0.974	
	N-IR	**-0.742**	-0.265	-0.365	0.750	0.721	0.589	0.169	
	AVE	**-0.926**	0.215	**-0.780**	**0.914**	**0.895**	**0.804**	**0.768**	
NT	IR	**-1.000**	0.713	-0.985	0.995	0.989	0.948	0.981	0.999
	N-IR	**-0.991**	0.325	-0.827	0.992	0.986	0.942	0.695	0.826
	AVE	**-0.997**	0.502	**-0.933**	**0.994**	**0.988**	**0.947**	**0.927**	**0.952**

According to correlation coefficient (r) values there were negative correlations between yield and shoot length under irrigated (-0.729), yield and 100-nut weight under irrigated (-0.997) and

non-irrigated (-0.999) condition, yield and internal nut weight under irrigated (-0.992) and non-irrigated (-0.999) condition, yield and shelling percentages under irrigated (-0.955) and non-irrigated (-0.979) condition, yield and nut length under irrigated (-0.985) and non-irrigated (-0.786) condition, yield and nut width under irrigated (-0.999) and non-irrigated (-0.742) condition, yield and nut thickness under irrigated (-1.000) and non-irrigated (-0.991) condition, positive correlation between yield and blank nut weight under irrigated (0.989) and non-irrigated (-0.895) condition. There was no particular correlation between yield and nut length.

Considering average value there were correlations between yield and blank nut (0.958), 100-nut weight (-0.999), internal nut weight (-0.997), shelling percentage (-0.969), nut length (-0.953), width (-0.926), and thickness (-0.997). As regards to correlations between each others except yield, correlations were found between shoot length and blank nut (-0.779), shelling (0.754) and nut length (0.790), between blank nut and 100-nut weight (-0.967), internal nut weight (-0.977), shelling (-0.999), nut length (-0.999), width (-0.780) and thickness (-0.993), between 100-nut weight and internal nut weight (0.999), shelling (0.976), nut length (0.962), width (0.914) and thickness (0.994), between internal nut weight and shelling (0.985), nut length (0.973), width (0.895) and thickness (0.988), between shelling percentage and nut length (0.998), width (0.804) and thickness (0.947), between nut length and nut width (0.768) and thickness (0.927), between nut width and nut thickness (0.952).

Changes and correlations between the yield, shoot growth and nut characteristics under irrigated and non-irrigated conditions for 'Ohaidi' cultivar are shown Table 5 and Figure 3. According to correlation coefficient (r) values there were negative correlations between yield and 100-nut weight under non-irrigated (-0.862) condition, yield and internal nut weight under non-irrigated (-0.949) condition, yield and nut length under irrigated (-0.986) condition, positive correlation between yield and blank nut weight under non-irrigated (0.837) condition, yield and nut width under non-irrigated (0.814) condition, yield and nut thickness under non-irrigated (0.910) condition. Considering average value there were correlations between yield and 100-nut weight (-0.696), nut length (-0.814) and thickness (0.763).

Table 5. Correlation coefficient (*r*) values of the growth and developmental parameters under irrigated and non-irrigated conditions for 'Ohaidi' cultivar

		Y	SH	BN	100-NW	INW	SP	FL	FW
SL	IR	0.541							
	N-IR	-0.490							
	AVE	-0.075							
BN	IR	0.011	-0.835						
	N-IR	**0.837**	-0.887						
	AVE	0.618	**-0.830**						
100-NW	IR	-0.261	0.671	-0.968					
	N-IR	**-0.862**	0.864	-0.999					
	AVE	**-0.696**	**0.768**	**-0.995**					
INW	IR	-0.073	0.799	-0.998	0.982				
	N-IR	**-0.945**	0.748	-0.970	0.980				
	AVE	-0.605	**0.839**	**-1.000**	**0.993**				
SP	IR	-0.342	0.606	-0.943	0.996	0.962			
	N-IR	-0.389	0.994	-0.830	0.803	0.669			
	AVE	-0.516	**0.893**	**-0.992**	**0.974**	**0.994**			
NL	IR	**-0.986**	-0.394	-0.176	0.417	0.237	0.493		
	N-IR	-0.531	-0.479	0.018	0.028	0.225	-0.573		
	AVE	**-0.840**	-0.479	-0.093	0.195	0.076	-0.032		
NW	IR	0.165	0.919	-0.984	0.909	0.972	0.870	0.001	
	N-IR	**0.814**	0.108	0.364	-0.407	-0.579	0.218	-0.924	
	AVE	0.179	**0.968**	**-0.663**	0.582	**0.675**	**0.751**	**-0.684**	
NT	IR	0.350	-0.599	0.940	-0.996	-0.960	-1.000	-0.500	-0.866
	N-IR	**0.910**	-0.807	0.989	-0.995	-0.996	-0.736	-0.132	0.500
	AVE	**0.763**	**-0.702**	**0.980**	**-0.995**	**-0.976**	**-0.947**	-0.289	-0.500

shelling (0.994), nut width (0.675) and thickness (-0.976), between shelling percentage and nut width (0.751) and thickness (-0.947), between nut length and nut width (-0.684).

The reasons underlying alternate bearing are classified as (environmental, climatic and soil properties) and intrinsic factors (nutritional status, endogenous balance of hormone and interactions between organs). Extrinsic factors affect bearing alternatively to yield because of climatic changes in rainfall and temperature (Elloumi et al., 2013). Intrinsic factors are related to endogenous hormones, nutrition and carbohydrate accumulation allocation between reproductive and vegetative organs of the plant (Nzima et al., 1997; Spann et al., 2008).

The results indicated that yield affected the vegetative growth and nut characteristics. In the year of low yield, shoot length was increased accordingly blank nut, 100-nut and internal nut weight, shelling percentage, nut length, width and thickness decreased. Irrigation increased shoot length.

Drought conditions decrease rate of cell division and expansion, stem elongation, plant water and nutrient uptake and water use efficiency (Li et al., 2009), shoot and root dry weight, leaf relative water content, total chlorophyll, carotenoids and increased oxidative stress products, some osmoregulators and antioxidant agents (Khoyerdi et al., 2016; Marcinska et al., 2013; Shamshiri and Fattahi, 2014; Spann et al., 2009).

Because of competition between developing fruit and vegetative growth, heavy fruit load uses the plants of nutrients and carbohydrates which are required for vegatative growth (Goldschmidt, 1999; Stevenson et al., 2000). A heavy fruit loaded branch will have little vegetative growth and little fruit on olive trees (Lavee, 2007).

Competition for energy resources between the vegetative shoot meristem and fruit reduce vegetative growth of the tree, so it designates the reproductive status of the tree the following year (Samach and Smith, 2013). For this reason in alternate bearing varieties cultural practices such as pruning, girdling, applications of plant growth regulators and flower and fruit thinning are to maintain a balance of vegetative and reproductive shoots (Pellerin et al., 2011; Dag et al., 2009).

In pistachio nut, the nut splitting is a genetic characteristic and nut splitting ratio is affected by rootstock, cultivar, plant nutrition, alternate bearing, climatic conditions, cultural management and pollen source (Takeda, 1979; Crane et al., 1982).

Percentage of split, non-split and blank nuts varied by shoot type, clusters harvested from long-shoots have higher total yield and split nut compared to short-shoot clusters because of the locally higher carbohydrate supply from the greater leaf area of the long-shoots (Kumar et al., 2016). Because of photosynthesis and the transportation of in other photo-assimilate (Marschner, 1995) to the developing nuts, 100-nut weight, split nuts, and internal nut weight increased.

Nutrient status of trees and fertilization has effects on nut yield and quality in pistachio. Nitrogen, phosphorus, potassium and foliar boron application influenced vegetative growth measurements, the flowering and fruit set, reduced buds abscission, blank pistachios and in turn improved nut quality characteristics including, nut length, width and thickness (Kumar et al., 2016).

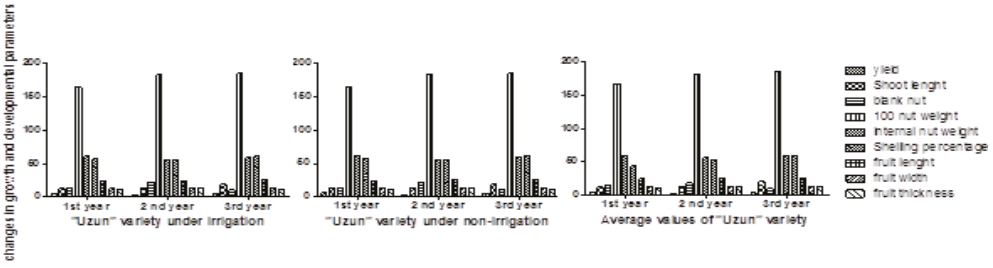

Figure 1. Changes in growth and nut characteristics under irrigated and non-irrigated conditions for 'Uzun' cultivar

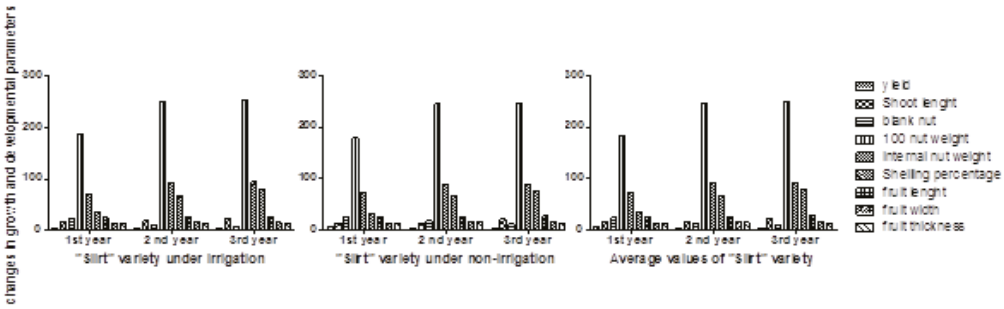

Figure 2. Changes in growth and nut characteristics under irrigated and non-irrigated conditions for 'Siirt' cultivar

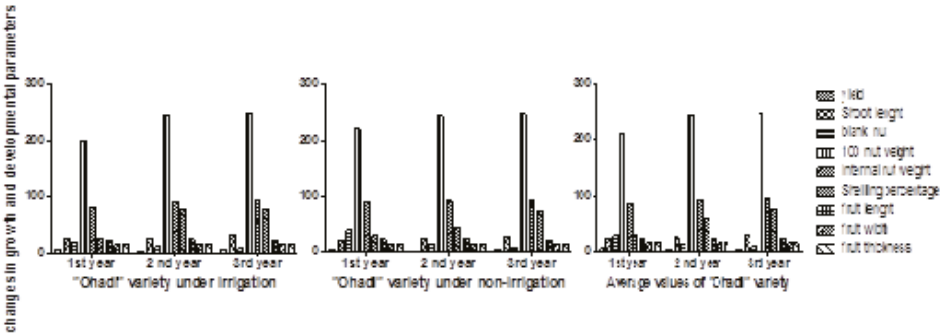

Figure 3. Changes in growth and nut characteristics under irrigated and non-irrigated conditions for 'Ohaidi' cultivar

Application of potasium improved nut quality in pistachio with an increased percentage of split nuts and 100-nut weight and reduced blank nut percentage (Zheng et al., 2001; Mimoun et al., 2004).

CONCLUSIONS

Alternate bearing and drought conditions are of the significant economic problems for fruit numbers and subsequently nut industries worldwide.

Hence, monitoring the changes in alternate bearing pistachio cultivars under drought conditions is of the essential steps for understanding alternate bearing mechanisms for the plant.

During the year with fewer yields, higher shoot length and lower blank nut, 100-nut weight, internal nut weight, split nut, nut length, width and thickness were obtained.

Effects of yield on vegetative growth and nut characteristics are more significant in 'Siirt' cultivar than the 'Uzun' and 'Ohaidi' cultivars.

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