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ROW AND PLANT SPACING EFFECTS ON THE YIELD AND YIELD COMPONENTS OF SAFFLOWER IN A MEDITERRANEAN-TYPE ENVIRONMENT

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ABSTRACT

This study was conducted to determine the effects of inter-row and intra-row spacing on two safflower cultivars under the Eastern Mediterranean conditions in Hatay, Turkey during 2010-2011 and 2011-2012 growing seasons. The field experiments were laid out in a split split plot design with three replications with two cultivars (Dincer and Remzibey) as a main plots, four inter-row spacing (15, 30, 45 and 60 cm) as sub-plot and three intra-row spacing (5, 10 and 15 cm) as sub-subplot. Seed yield and yield-related traits were lower in both cultivars in 2012 comparing to previous year probably due to lower rainfall. Two years' data indicated that cultivars, inter-row and intra-row spacing significantly affected growth, yield and yield components of safflower. Increasing plants population reduced yield components and yield of individual plants, but increased yield per unit area. Low plant density resulted in significantly higher branches/plant, heads/plant, seeds/head. The highest seed yields per hektare were obtained with sowing safflower cultivars at 5 cm intra-row spacing in 45 cm spaced rows in 2011, and in 30 cm spaced rows in 2012. Our results indicated that higher plant density can be advantageous under yield limiting conditions while sowing winter safflower at 45 x 5 cm inter- and intra-row spacing can be recommended for regular seasons in Mediterranean-Type Environments.

Keywords: *Carthamus tinctorius*, cultivar, oil content, plant density, seed yield.

INTRODUCTION

Safflower (*Carthamus tinctorius* L.) is also known as false saffron, bastard saffron, thistle saffron, dyer's saffron kardiseed, kusum, kazhirak is a member of the family *Compositae*. It is a flowering plant which has been grown for centuries in small plots over a vast area from China to the Mediterranean region (Weiss, 1971). Safflower is believed to have originated in the area encompassed by southern Turkey, southern USSR, western Iran, Iraq, Syria, Jordan and Israel (Sing and Nimbkar, 2007; Akinerdem and Ozturk, 2008). Safflower which originated in the Eastern Mediterranean (Knowles, 1989), cultivated primarily for seed, which is used as high-quality vegetable oil and as birdseed (Koutroubas et al., 2009). Flowers are known to have many medical properties (Dajue and Mundel, 1996; Amoghein et al., 2012b; Sharif Moghaddasi and Omidi, 2016) and cut flowers (Uter, 2008) and its leaves and shoots are also used for salad (Nimbkar, 2002). Furthermore, safflower has a good agronomic characteristics numerous benefits in rotations with cereals and other crops (Bradley and Johnson, 2001). The importance of safflower has increased in recent years, especially with the interest in the production of biofuels (Bergman and Charles, 2008; Sujatha, 2008). It is well adapted to dry land conditions mainly because plants have a deep tap-root than can extent to a depth of 220 cm and xerophytic spine attributes that contribute to good drought and heat tolerance (Kaffka and Kearney, 1998; Weiss, 2000). Although safflower is a very important vegetable oil plants, it has been grown on a very limited rate (about 39.352 ha) in Turkey, with an estimated total production of 58 000 tones and average seed yield of 1474 kg/ha (FAO, 2016). Calıskan et al. (1998) reported that safflower can be an alternative oil crop for winter sowing in poor lands in Hatay region.

There are many factors that affect productivity in agriculture (Yau, 2009; Albayrak et al., 2011). Safflower growth, yield and yield composition and quality of seeds are also influenced by many factors like genotype, environment and agronomic practices (Dajue and Mundel, 1996; Koutroubas et al., 2009; Jajarmi et al., 2014). Agronomic practices such as row spacing and plant distance (plant density) of safflower vary considerably worldwide depending on each growing region, environmental condition, production systems and safflower cultivar (Mundel et al., 1994), germination rate, soil fertility and water availability (Omidi et al., 2009; Emongor et al., 2013; 2015). Plant spacing is one of the agronomic practices that influence crop growth and development. Besides, plant spacing is among the factors affecting safflower yield and seed oil percentage. Optimization of plant density positive affects the absorption of nutrients and the amount of plant exposure to light and lead to higher yield. In addition, plant density of safflower crop is an important factor and increasing plant density provides to control of weeds and the end of result, yield and yield components was to higher (Naghavi, 2012). Many studies have investigated to determine optimum row spacing and plant distance for safflower under different environmental conditions. Several field trials indicated that row spacing and seeding rate has significantly affected safflower seed and oil yield. In Nebraska, 15-23 cm row spacing produces give the highest seed yields (Weiss, 2000). Esendal (1986) determined that the seed yield of safflower increased appreciably as the row distance was decreased from 90 to 18 cm. and the highest seed yield obtained from 18 cm rows in Erzurum Valley. Abd El-Mohsen and Mahmoud (2013) indicated that the highest plant density (200.000 plants ha^{-1}) was the best treatment in research to attain high safflower seed yield under different environmental conditions. In Iran, row spacing greatly affected seed yield and 15 cm row spacing was recommended by Mohammadi and Karimizadeh (2013). Moatshe et al. (2016) reported that seed yield significantly increased as plant density increased from 62.500 to 100.000 plants per hektare. Emongor et al. (2013) reported that increasing plant density of safflower from 100.000 to 250.000 plants per hektare significantly decreased seed yield. Elfadl et al. (2009) indicated that seed density did not reveal any significant variation in seed yield, oil content, and oil yield. Several researches indicated that cultivar gave different response to row spacing and plant distance (Uslu et al., 1998; Omidi et al., 2009, Mohamadzadeh et al., 2011; Omidi et al., 2012; Sharif Moghaddasi and Omidi, 2016; Uke et al., 2017).

The objective of this study was to determine the seed yield and yield components of Dincer and Remzibey safflower cultivars to various row spacing and plant distances in a row on the Mediterranean-Type Environment.

MATERIALS AND METHODS

Field experiments were conducted in 2010-2011 and 2011-2012 at the Experimental Farm of the Faculty of Agricultural, Mustafa Kemal University in Hatay (36º 39’ N, 36º 40’ E; 83 m elevation), located in the Eastern Mediterranean region of Turkey. The soil of the experimental site, developed from alluvial deposits of river terraces, is typical for the Eastern Mediterranean region of Turkey, and is classified as Chromoxeret by USDA Soil Taxonomy (Anonymous, 1998) and as Vertisol by FAO/UNESCO (1974) having relatively high clay content with the predominant clay minerals smectite and kaolinite. Soil samples were collected from experimental area at 0-40 cm depth before basal fertilizer application to test initial soil characteristics, and soil test results are presented in Table 1. The province of Hatay has typical Mediterranean climate with hot and dry summers and mild and rainy winters. The daily climatic data were obtained from the agro-meteorological station located in a state farm about 1 km far from the experimental site. The mean values of the climatic date are given in Table 2.

Table 1. Initial soil properties of the 0-40 cm soil layer of the experimental site

Soil properties	
pH[a]	7.9
$CaCO_3$ (g kg^{-1})	31.17
Organic matter (g kg^{-1})	3.01
Sand (g kg^{-1})	9.40
Silt (g kg^{-1})	27.68
Clay (g kg^{-1})	62.92
N[b] (g kg^{-1})	0.13
Fe[c] (mg kg^{-1})	5.77
Zn[c] (mg kg^{-1})	1.35
Mn[c] (mg kg^{-1})	3.08
Electrical conductivity (dS m^{-1})	2.0
Soil order	Vertisol

[a] pH and Electrical conductivity were determined in saturation extracts.
[b] N content was determined with Khjeldahl method.
[c] Fe, Zn and Mn contents were determined with DTPA extraction method.

Two safflower cultivars (Dincer cv. is a tall, thick, stemmed and spineless type and Remzibey cv. is a short, spiny type) were used in experiments. The experimental design was a split-split plot in randomized complete block design with three replications. Main plot treatments consisted of two cultivars. Sub-plot treatments were four row spacing; 15, 30, 45 and 60 cm. Sub-subplots treatments were also three plant distance in a row; 5, 10 and 15 cm. Each plot was consisted of 4 rows with 5 m long. Seeds were planted on 10 November 2010 and 29 November 2011 by hand. The pre-sowing herbicide, *trifluralin* (*α,α,α*-trifluoro-2,6-dinitro-*N,N*-dipropyl-*p*-toluidine), was applied to soil at the rate of 960 g a.i. ha^{-1}, and the plots were maintained as weed-free by hand weeding during growing period. Phosphorus (P) was applied at planting to each plot at 60 kg P ha^{-1} as triple super-phosphate. Nitrogen (N) was applied 60 kg P ha^{-1} as ammonium nitrate. The first half of the N was broadcast by hand and incorporated with planting. The subsequent part of the N was side-dressed by hand and incorporated at bolting stage. The plants were thinned after full emergence as mentioned in plant spacing. Safflowers were harvested on 12 June 2011 and 13 July 2012. Ten plants were harvested at maturity from the first and fourth rows of each plot for measuring number of branches per plant, number of head per plant, number of seed per head. Representative samples of head were hand and thousand grain weight and oil content were determined. The seeds were oven-dried at 40 ^{0}C for 4 h in a ventilated oven until reaching a moisture content of about 5%, and were then ground with a Warring blender. Five grams of safflower seeds were extracted with petroleum ether for 6 h in a Soxhlet system, according to The American Oil Chemists Society (AOCS) method (AOCD, 1993). Seed yield was estimated by harvesting 5 m of two central rows at maturity.

Table 2. Mean temperature, monthly rainfall, and relative humidity during the growing period of 2010-2011 and 2011-2012

Months	Mean Temperature (ºC)			Rainfall (mm)			Relative humidity (%)		
	Long-term	2010 2011	2011 2012	Long-term	2010 2011	2011 2012	Long-term	2010 2011	2011 2012
November	14.2	16.5	15.1	99.6	-	58.6	60.0	51.7	79.2
December	10.0	11.3	8.2	180.2	257.2	190.9	72.5	72.4	85.4
January	8.8	9.2	7.4	191.2	106.9	418.1	74.1	69.6	82.2
February	11.1	12.7	8.5	170.4	154.8	243.6	68.0	71.6	79.2
March	14.6	13.7	11.8	143.1	143.5	105.2	61.5	64.2	59.3
April	18.1	17.0	18.8	103.2	130.4	16.5	61.5	66.1	64.2
May	21.9	20.9	21.6	78.6	65.1	97.6	63.1	64.4	61.4
June	25.2	24.7	26.3	24.7	86.3	1.6	63.2	66.7	58.4
July	27.7	28.0	28.9	6.9	-	14.1	64.0	63.4	58.4

Data for evaluated traits in each year were statistically analyzed using a standard analysis of variance technique for a split-split plot design using the general linear model procedure in the Statistical Analysis System (SAS Institute, 1996). Means were separated using Fisher's protected least significance difference (LSD) test at 95% level of probability.

RESULTS AND DISCUSSION

Yield and yield components

The data regarding to yield and yield components of different cultivar, row spacing and plant distance in 2011 and 2012 years has been presented in Table 3. Data of variance analysis on Table 3 showed that the effect of the cultivar, row spacing, plant distance and row spacing x plant distance interaction on branch number per plant were statistically significant at 1% probability level in the first year. In the second year all treatments and interactions on branch number per plant were statistically significant at 1% probability level. Number of branch per plant significantly varied with row spacing and plant distance in both years. According to the means in Table 3, the maximum number of branches was observed from 60 cm row spacing and 15 cm plant distance where the minimum values obtained from 15 cm row spacing and 5 cm plant distance in both years. In a previous study, it was reported that wider row spacing and plant distance increased biomass of the plant by producing healthy plant parts by receiving maximum sun light for the photosynthesis (Oad et al., 2002). The study results harmony with the previous findings of Oad et al. (2002), Sharif Maghaddasi and Amoghein et al. (2012b) and Sharif Maghaddasi and Omidi (2016) who reported that growth parameters of safflower crop are significantly influenced by row spacing and plant density and increasing the plant density may be the primary reason to decrease light intensity around plants and diminished branching.

The results show that by row spacing more widely from 15 to 60 cm and by plant distance from 5 to 15 cm led to increase in number of head per plant from 8.2 to 16.4 and 11.3 to 14.9 respectively in 2011 (Table 3). Similar results were obtained in also 2012 and row spacing at 60 cm and plant distance at 15 cm produced highest number head per plant. In 2012 year, the number of head per plant was lowest than the 2011 (Table 3). This may be the result of increasing temperatures especially in April, May, June and low rainfall during the flowering and filling period in April and June (Table 1) leading to reducing the number of head per plant. Number of head per plant of Remzibey cultivar was higher than the Dincer cultivar. In 2012 year, the average head number per plant in interaction effects between row spacing with plant distance and cultivar with plant distance and cultivar with row spacing were also significant and revealed that widening distance between the plants, which caused competition decrease among the plant, also increased the head number of plant. Reduction of head number per plant with decreasing row spacing and plant distance may be due to the plants competition to uptake nutrients, sunlight, shadowing leaves and branches of upper parts and decreasing seed fullness of side branches. Additionally, increasing number of branches per plant may be also the main cause of increasing number of head per plant due to decreasing plant density. In 2011 and 2012 years, the highest number of head per plant was recorded in 60 x 15 cm pattern as 20.6 and 18.4 respectively. Whereas the lowest heads number values were detected in 15 x 5 cm pattern in both years (Table 3). These results agree with previous results (Oad et al., 2002; Elfadl et al., 2009, Sharif Maghaddasi and Omidi, 2009, Emami et al., 2011, Amoghein et al., 2012a; Vaghar et al., 2014; Hamza, 2015; Moghaddasi and Omidi, 2016; Uke et al., 2017).

Table 3. Effect of cultivar, row spacing and plant distance on number of branch per plant, number of head per plant and number of seed per head of safflower

	Number of branch per plant		Number of head per plant		Number of seed per head	
Treatment	**2011**	**2012**	**2011**	**2012**	**2011**	**2012**
Cultivar (C)						
Dinçer	4.8	4.3	12.0	10.1	24.2	26.5
Remzibey	5.3	4.8	14.1	10.5	25.8	24.6
LSD (5%)	0.23	0.07	1.14	0.20	0.50	-
Row Spacing (RS)						
15	3.7 c	3.7 d	8.2 d	4.9 c	24.6 b	21.6 b
30	5.1 b	4.5 c	13.2 c	10.8 b	25.0 ab	25.9 a
45	4.9 b	4.7 b	14.3 b	11.1 b	25.2 a	27.3 a
60	6.4 a	5.4 a	16.4 a	14.4 a	25.4 a	27.5 a
LSD (5%)	0.21	0.13	0.77	0.40	0.46	3.00
Plant Distance (PD)						
5	4.7 c	4.2 c	11.3 c	8.6 c	22.3 c	23.6 b
10	5.0 b	4.6 b	12.9 b	10.3 b	25.7 b	25.4 ab
15	5.5 a	4.9 a	14.9 a	12.0 a	27.3 a	27.6 a
LSD (5%)	0.18	0.11	0.67	0.35	0.40	2.60
C	**	**	**	*	**	ns
RS	**	**	**	**	**	**
PD	**	**	**	**	**	*
C x RS	ns	**	**	**	**	ns
RS x PD	**	**	ns	**	**	ns
C x PD	ns	**	ns	**	**	ns
C x RS x PD	ns	**	ns	ns	**	ns
CV (%)	6.15	4.31	8.78	5.81	2.74	17.49

*P < 0.05, **P < 0.01; ns, non-significant

The most important yield ingredient of safflower plant is seed number (Dajue and Mundel, 1996). Results of the variance analysis showed that the number of seed per head was significantly influenced by cultivar, row spacing and plant distance in 2011 but in 2012 cultivar was not significant (Table 3). In 2011 year, all treatments and interactions on seed number per head were statistically significant at 1% probability level. In 2011 year the highest seed number per head was obtained from 60 cm row spacing and 15 cm plant distance with mean 25.4 heads and 27.3 heads respectively. Also in 2012 year, the highest seed number per head was obtained from 60 cm row spacing and 15 cm plant distance with mean 27.5 seeds and 27.6 seeds respectively. The lowest seed number per plant was obtained from 5 cm plant distance. Plants grown at wider row spacing and plant distance received a higher red/far red light ratio compared with narrow row spacing and plant distance which caused a greater portion of total vegetative dry matter to be partitioned into branches (Kasperbauer, 1987). Moreover, inter-plant competition for nutrients and water reduced at wide row spacing and plant distance and as a result of this, greeter number of seed per head created. Some researchers conducted their research emphasized similar findings in their experiments (Oad et al., 2002; Emami et al., 2011; Hamza, 2015; Sharif Moghaddasi and Omidi, 2016).

Variance analyzing results of 100-seed weight indicated on Table 4. Cultivar, row spacing, plant distance and interactions had significant effect in 2012 year, while only cultivar and row spacing treatments had significant effect on 100-seed weight in 2011 (Table 4). 100-seed weight of Dincer cultivar was higher than the Remzibey cultivar in both years. Beyyavas et al. (2011) reported that the genotype and ecological condition were two important factors, which were effective on 1000 seed weight. In 2011, the highest 100-seed weight was obtained at 45 cm row spacing, averagely 3.95 g and the lowest 100-seed was obtained using 15 cm row spacing averagely 3.79 g. that was 4% lower (Table 4). Also in 2012 year, the highest 100-seed weight was obtained from 45 cm row spacing treatment and 100-seed weight in 2012 year was higher than 2011 year. Results of the study showed that 100-seed weight gradually increased with increasing of plant distances, but this variation statistically was not significant in 2011 (Table 4). In both years, the highest 100-seed weight was obtained at 15 cm plant distance with mean 3.87 g and 4.7 g respectively. This was the result of interplant competition positively affecting seed development during the seed filling stage. These results are in agreement with those obtained by Gonzales et al. (1994) and Emami et al. (2011).

Table 4. Effect of cultivar, row spacing and plant distance on 100-seed weight, seed yield and oil content of safflower

Treatment	100-seed weight (g)		Seed yield (kg ha^{-1})		Oil content (%)	
	2011	2012	2011	2012	2011	2012
Cultivar (C)						
Dinçer	4.05	5.04	3261.8	2721.2	26.9	31.4
Remzibey	3.69	4.30	3441.6	2480.4	27.2	30.6
LSD (5%)	0.17	0.08	52.33	109.86	-	0.23
Row Spacing (RS)						
15	3.79 c	4.39 b	3327.4 b	2221.4 c	26.4 c	31.3 ab
30	3.82 bc	4.44 b	3382.2 b	3050.3 a	27.1 b	30.2 c
45	3.95 a	4.98 a	3632.5 a	2509.3 b	28.6 a	31.7 a
60	3.87 b	4.37 b	3064.9 c	2472.2 b	26.1 c	30.9 b
LSD (5%)	0.07	0.09	89.31	54.25	0.43	0.44
Plant Distance (PD)						
5	3.86 a	4.39 c	3636.2 a	3141.4 a	25.5 c	29.4 c
10	3.86 a	4.56 b	3339.3 b	2576.0 b	27.2 b	31.3 b
15	3.87 a	4.69 a	3079.7 c	1972.8 c	28.5 a	32.3 a
LSD (5%)	0.06	0.07	77.35	46.98	0.37	0.39
C	**	**	**	**	ns	**
RS	**	**	**	**	**	**
PD	ns	**	**	**	**	**
C x RS	ns	**	*	**	**	**
RS x PD	ns	**	**	**	**	**
C x PD	*	*	ns	**	**	**
C x RS x PD	ns	**	**	**	**	**
CV (%)	2.57	2.78	3.97	3.15	2.37	2.13

*P < 0.05, **P < 0.01; ns, non-significant

The seed yield of safflower was significantly affected by cultivar, row spacing and plant distance in both years (Table 4). Seed yield significantly varied among row spacing and plant distance. The highest seed yields were obtained from 45 cm row spacing with 3632.5 kg ha^{-1} in 2011 and 30 cm row spacing with 3050.3 kg ha^{-1} in 2012. Ali Zadeh et al. (2012), Sharif Maghaddasi and Omidi (2016) also reported that seed yield increase using 30 cm row spacing. Also plant spacing effect was significant on seed yield. In 2011 and 2012 years, the highest seed yield obtained from 5 cm plant distance with mean 3636.2 kg ha^{-1} and 3141.4 kg ha^{-1} respectively. Generally, in our study, seed yields in 2011 were higher than the other experiment year. The main reason for this difference was the distinction among climatic conditions of growing seasons. In the 2011 growing season, amount of rainfall was higher than the other year. Especially, because of the higher amount rainfall after March increased the seed yield (Table 2). Many researchers studied row spacing and plant distance effect in safflower crop and demonstrated that low to medium densities produced more seed yield but in too narrow plant spacing, yield reduced due to increasing competing to uptake water, nutrients and light (Emami et al., 2011; Zarei et al., 2011; Hamza, 2015). However, many researches indicated that yield and yield components decreased due to increasing plant density in safflower (Gonzalez et al., 1994; Oad et al., 2002; Amoghein et al., 2012; Emongor et al., 2013; Moatshe et al., 2016), but increasing plant population equalized seed yield. In 2011 and 2012 years our study results shown that the highest seed yields were obtained from 30 cm and 45 cm row spacing and narrow plant row spacing caused a reduction around in number of head per plant and number of seed per head. Decrease in yield and yield components in higher plant population could be explained by enhanced competition for nutrients, water and sunlight. Light intensity is the most important limiting factor the seed yield. When the plant density increases, the shading increases, which limits the photosynthesis (Ali Zadeh et al., 2012). This limitation in photosynthesis directly decreases the dry matter content accumulated in the plant, and in return, decreases the yield. Additionally, lower level of yield is related with decreased head number, seed number per head and 100-seed weight under higher plant densities. Significant differences were also observed among safflower cultivars for seed yield (Table 4). In first year, seed yield of safflower cultivars were higher than the second year. Environmental factors, especially temperature, are the key factor which influences plant growth and development. Temperature during the period of seed development and maturation, might have affected yield. In the 2012 growing season, mean temperature especially during the maturation was higher than the other year. Mean temperature during the period of flowering and pollination in 2011 year was optimum and as a result seed yield in 2011 year was higher than 2012 year. In addition, amount of rainfall and distribution during the growing period play an important role in yield. Seed yield in 2011 year was positive significantly influenced by rain amount and distribution in our research.

The interaction effect of cultivar, row spacing and plant distance were significant on seed yield (Table 4). In 2011 and 2012 years, the highest seed yield were obtained from Remzibey cultivar x 45 cm row spacing x 5 cm plant distance and Dincer cultivar x 30 cm row spacing x 5 cm plant distance respectively (Figure 1). Since the seed yield of safflower is determined by several environmental factors (climatic factors such as temperature, rainfall, humidity and soil properties, fertility, etc.) as well as genotypic structure, it is probable that the difference between results of the research is mainly because of the environmental conditions.

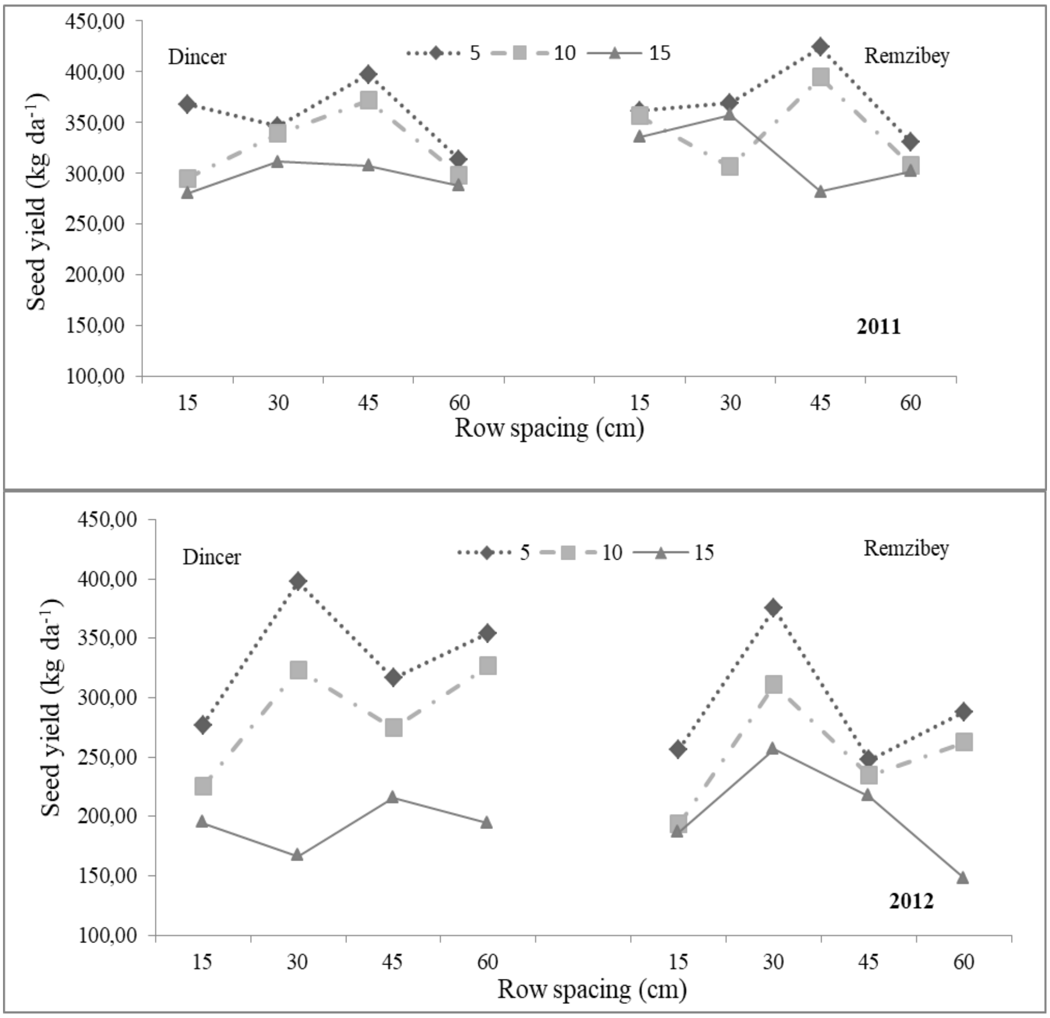

Figure 1. Seed yield of Dincer and Remzibey cultivars as affected by row spacing and plant distance in 2011 and 2012.

Oil content

Oil content is one of the most important components, which play a crucial role in the safflower seed quality. Data of variance analysis on Table 4 showed that the effect of the cultivar (except 2011), row spacing, plant distance and all of the interaction on seed oil content were statistically significant at 1% probability level in both years. In the first year, the oil contents were 24.1-32.2 % and the highest oil content was obtained from Dincer cultivar, 45 cm row spacing 15 cm plant distance and in the second year, the oil contents 26.2%-34.3% and the highest oil content was obtained from Dincer, 60 cm row spacing and 15 cm plant distance (distance data was not shown). The effect of row spacing on oil content was significant and 45 cm row spacing gave the highest (28.6% and 31.7%) oil rate in 2011 and 2012 respectively. On the other hand, the effect of plant distance on oil content was significant and 15 cm plant distance gave the highest (28.5%-32.3%) oil content in 2011 and 2012 respectively. In general, the level of oil content in 2012 year was higher than in 2011 year. The results showed that there was a significant increase in seed oil content by increasing row spacing and plant distance. Same trend was observed by Yau (2009), Ali Zadeh et al. (2012), Amoghein et al. (2012b) and Hamza (2015). However, Emami et al. (2011) and Moghaddasi and Omidi (2016) found that increasing plant densities increased seed oil content. Enhanced seed chemical properties, including seed oil content, could be explained by better development of plants in a plot where there is less number of plants per unit area, therefore less competition for environmental factors such as minerals, water and light.

A lot of factors such as cultivar, environmental factors and location influence on content of oil in safflower seed. Especially cultivar is the most important factor for oil content. The difference in oil content is due to the genetic structure of the cultivar. Cultivar it can be related to disability of plants to use environment potential. Previous studies indicated that the oil content of safflower mostly depends more on the cultivar than the agronomic application and environmental conditions (Rahamatalla et al., 2001; Jajarmi et al., 2008; Emami et al., 2011; Kose and Bilir, 2017).

CONCLUSIONS

As a result of this two-year field study, it was concluded that plant density (row spacing and plant distance) is an important factor in crop management for optimizing productivity in safflower. The cultivar, row spacing and plant distance significantly affected some important growth, yield and yield components of safflower. According to the results, increasing plants population reduced yield components and yield of individual plants but increased yield per unit area. Low plant density resulted in significantly higher branches per plant, heads per plant, seeds per head. The highest seed yields per hectare were obtained with sowing safflower cultivars at 5 cm intra-row spacing in 45 cm spaced rows in 2011, and in 30 cm spaced rows in 2012. Our results indicated that higher plant density can be advantageous under yield limiting conditions while sowing winter safflower at 45 x 5 cm inter- and intra-row spacing can be recommended for regular seasons in Mediterranean-type environments.

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