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Response of Safflower (Carthamus tinctorius L.) to Planting Rate and Row Spacing in a High Altitude Enviroment

Araştırma Makalesi/Research Article

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Abstract

Safflower (Carthamus tinctorius L.), has the potential to be an important oilseed crop in Eastern Anatolia, Turkey. In this region with a semi-arid climate, there is no scientific study about row spacing and planting rate in safflower. Therefore, this study was conducted to investigate the effects of row spacing and planting rate on yield and agronomic properties of safflower cultivars (Dinçer and Yenice) in dry conditions, in the years 2013 and 2014. Three different row spacings (20, 40 and 60 cm) and planting rates (20, 40 and 60 kg ha-1) were tested. In both study years, it was determined that seeding rate, row spacing and cultivars have significant effects on plant growth, yield and yield components. The cultivars responded similarly to both treatments that row spacing and planting norm in terms of seed yield in both research years. It was determined that the examined plant characteristics were significantly affected by the treatments, and the oil concentration, seed, and oil yield increased with increased row spacing and planting rate. The results obtained from this study emphasize the importance of the choice of suitable row spacing and planting rate in safflower production in semi-arid environments and the seed yield in safflower could be increased by narrow planting (i.e.the 20 and 40 cm row spacings with 60 kg ha-1planting rate.

Keywords
planting rate, row spacing, Safflower, seed yield.

Kuru Koşullarda Farklı Ekim Normları ve Sıra Arası Mesafelerin Aspir (Cartthamus tinctorius L.) Bitkisinin Verim ve Verim Unsurları Üzerine Etkisi

Özet

Aspir (Cartdamus tinctorius L.), Türkiye'nin doğusunda, önemli bir yağlı tohum bitkisi olma potansiyeline sahiptir. Bu bölgede aspir yetiştiriciliğinde sıra arası ve ekim normu hakkında sınırlı sayıda bilgi bulunmaktadır. Bu nedenle, çalışma 2013- 2014 yıllarında kuru şartlarda sıra arası ve ekim normunun aspir (Dinçer ve Yenice) çeşitlerinin verimi ve agronomik özellikleri üzerindeki etkilerini araştırmak amacıyla yürütülmüştür. Üç farklı sıra arası mesafe (20, 40 ve 60 cm) ve üç farklı ekim normu (20, 40 ve 60 kg ha-1) test edilmiştir. Her iki araştırma yılında bitki büyümesi, verim ve verim bileşenleri üzerinde ekim normu, sıra arası ve çeşitlerin önemli etkileri olduğu belirlenmiştir. Çeşitler her iki araştırma yılında tohum verimi bakımından sıra arası ve ekim normu uygulamalarına benzer şekilde tepki vermişlerdir. İncelenen özelliklerin uygulamalardan önemli derecede etkilendiği, yağ oranı, tohum ve yağ veriminin sıra aralığı ve artan ekim normuna paralel olarak arttığı belirlenmiştir. Araştırmadan elde edilen sonuçlar, yarı kurak iklime sahip ekolojilerde, kuru şartlarda aspir bitkisinde uygun sıra arası ve ekim normu uygulamalarının önemini vurgulamaktadır. İncelenen karakterler üzerine 40 cm sıra aralığı, 60 kg ha-1 ekim normu daha iyi sonuçlar üretmiş ve aspirde tohum veriminin sık ekim uygulamasıyla artırılabileceği görülmüştür.

Anahtar Kelimeler
Soybean, apical dominance, pruning, branching, yield

1. INTRODUCTION

Due to irregular and low precipitation in semi-arid regions, the plant numbers that can be economically produced is very limited (Flagella et al. 2002, Reddy et al. 2003). One of the most important crops to be grown under these conditions is safflower. Safflower has increasing importance as an oil plant due to its high drought resistance, adaptability to various soil conditions, being suitable for agricultural mechanization and low input costs (Cosge and Kaya 2008).

Although safflower has a wide production potential, it is acknowledged in some regions and grown by traditional methods. To contribute to the production, studies should be carried out to increase the cultivation area and yield of safflower plant, which can be an important potential among oilseed plants. In our country, safflower has not an important place in the cultivation and production of oilseed plants. The reasons for this situation are inappropriate agronomic applications and using low yield and oil content varieties, marketing, evaluation, and organization problems.

Plant density may affect both vegetative and generative development in cultivated plants and it varies significantly according to environmental conditions and production systems (Jajarmi et al. 2014). Many factors can affect the yield of the safflower plant. The most important of these factors are row spacing and planting rate. As in other plants, the optimum seeding rate or plant density is the key points for high yield and quality products in safflower. The planting of high-yielded varieties under suitable climatic conditions and appropriate agronomic practices are the basis for obtaining high yield per unit area. It is known that using appropriate row spacing and seed amount, the plants develop better, and the branch numbers, heads and the seed numbers per head increase (Umrani et al. 1984). Studies have shown that row spacing and planting norm significantly affect the seed and oil yield of safflower. Weiss (1983) reported that the planting frequency may vary according to the variety used in the safflower plant. Small-grained plants such as safflower are planted lower seeding rate than in the past. In lower rates of sowings, it is expected to be more branches, a long flowering period, and late crop maturity, also there will be an increasing demand for water and nutrients in the soil, especially in dry conditions. Therefore, the response of the plants to plant density varies depending on the soil moisture content. But, safflower can tolerate water and nutrient deficiencies due to the deep root system that enables nutrients and moisture to be utilized. According to a study, has been conducted to evaluate the suitable plant spacings for safflower under different ecological conditions and it has been detected that the suitaple row spacings were 15-23 cm for high seed yield (Weiss 2000). Naderi et al. (2015) determined that the distance between the rows significantly affects the yield in safflower and the narrower row spacing is more suitable for yield. Masoume et al. (2011) tried four different row spacings and they obtained the highest seed yield (1214 kg da-1), the head number (12,18), the number of seed per head (24.3) from 30 cm row spacing. In another study conducted in Iran, it was reported that the seed yield may be affected depending on changing of row spacing and the highest yield was obtained from 15 cm row spacing (Modammadi and Karimizadeh 2013). Similar to row spacing, it is essential to determine the ideal plant density per unit area to obtain the maximum yield. Plant density is an important factor to regulate the microenvironment in the safflower cultivation area and it can affect seed yield and oil ratio.

Optimization of this factor positively affects the nutrient absorption and light exposure of plants, resulting in high yields. The increase in seed yield depends on the high number of plants per m2. Moatshe et al. (2016) demonstrated that increasing plant density from 62,500 to 100,000 plants per hectare, increased the seed yield significantly. In many studies, it was stated that dense planting increases yield (Amoughein et al. 2012b, Vagdar et al. 2014). Berglund et al. (1998), plant density is too low, causes to increasing of weed competition, Emongor et al. (2013) showed that as increase the plant density seed yield significantly decreased. Elfadl et al. (2009) stated that plant density had no important effect on seed yield, oil rate and yield. Abd El-Mohsen and Mahmoud (2013), reported that the highest yield was determined in the highest plant density sites (200,000 plants ha-1) in different ecological conditions. Some studies showed that varieties have different responses to inter row spacing and sowing density (Omidi et al. 2009, Mohamadzadeh et al. 2011, Omidi et al. 2012, Sharif Moghaddasi and Omidi 2016, Uke et al. 2017).

Safflower is a new plant for the Eastern Anatolia region of Turkey. It is important to determine the suitable variety, appropriate seeding rate, and planting norms for commercial production in the region. The region where the research was conducted shows semi-arid climate characteristics that has low precipitation in summer period. Therefore, to optimize safflower yield in low rainfall areas, a balance should be maintained between the amount of vegetative growth and soil moisture. In this study, it was aimed to evaluate the suitable row spacing and planting rate for yield and agronomic characters of safflower varieties in dry conditions and to determine the optimal row spacing and seeding rate in safflower production.

2. MATERIAL AND METHODS

This research was carried out in 2013-2014 in Erzurum province (1663 m altitude, 41° 67 'east longitude, and 39° 97' north latitude) located in the Eastern Anatolia Region of Turkey, characterized by semi-arid climate. Terrestrial climatic conditions are observed in the region and the autumn, summer and spring seasons are short whereas the winter period is long. In this region, plant diversity and yield is restricted by semi-arid climatic conditions and the short vegetation period. The fact that the safflower plant is more resistant to low precipitation and temperatures than other plants make it possible to grow this plant in the region.

The meteorological data of the study area are given in Figure 1. In the first study year (2013), the total precipitation value (60.4 mm) was lower than the long-term average (187.5 mm), the monthly average temperature (3.1 0C) was the same as the long-term average and the relative humidity (38.6%) was lower than the long-term average (52.6%). In the second study year (2014) total precipitation was lower than the long-term average, higher than the first year. However, the monthly temperature and relative humidity values of 2014 were higher than both 2013 and the long-term average. In the period between May and September, which is the active growth period of field crops, temperatures were close to each other in both years.

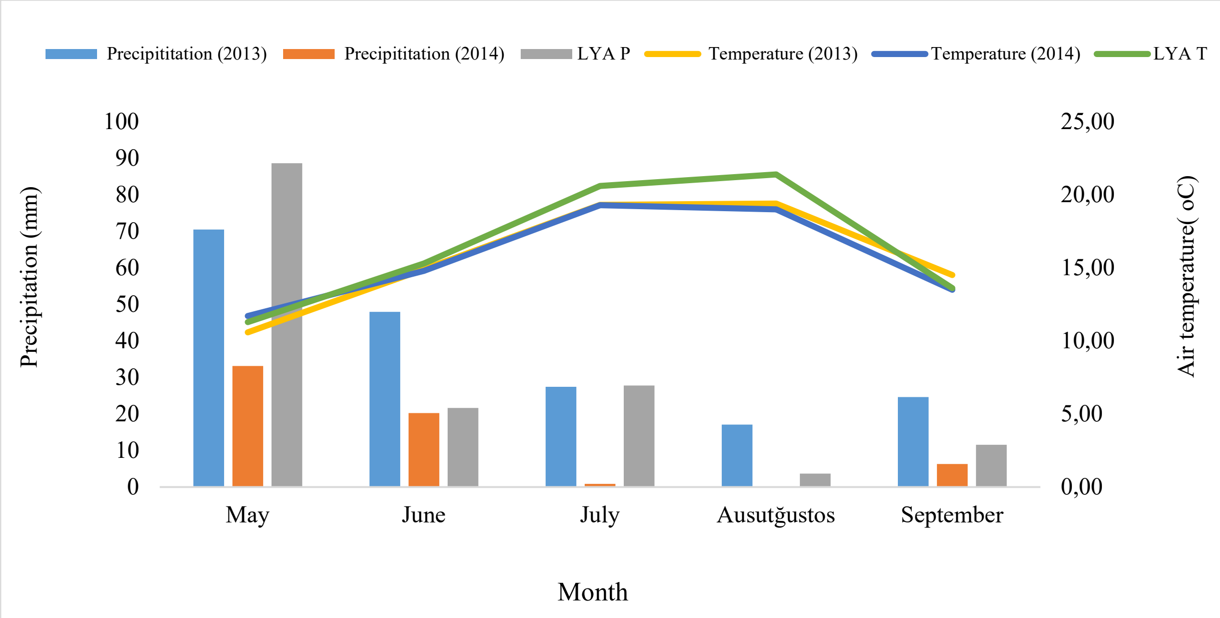

Figure 1.Some important climate data of the study area for long-term average and 2013-2014.

Before planting, soil samples were taken from the experimental areas and some soil chemical and physical characteristics were analyzed in these samples. According to the soil analysis results, the soil texture was clay loam, the pH values varied between 7.25 and 7.71. The lime content varied between 0.96% to 3.10%, the available phosphorus was 3.62-3.92 kg da-1, the potassium was 82-101 kg da-1, and the organic matter contents were 1.49-1.70%. Accordingly, the soil of the study site is moderately alkaline, low in phosphorus, medium in organic matter, and sufficient in terms of potassium (Sezen 1995).

The study was contucted in the Randomized Complete Blocks design with 4 replications. In the study, 2 varieties (Dinçer and Yenice), three different row spacing (20, 40 and 60 cm) and three different seeding rate (20, 40 and 60 kg ha-1) were examined. The varieties were the main plots, row spacing subplots, and seeding rate sub-sub plots. Sowing was done on 13 May 2013 and 18 May 2014 with a plot seeder. For fertilization, 40 kg ha -1 Triple superphosphate (46% P_2O_5) and 60 kg ha-1 ammonium sulfate (21% N) were applied to the experimental area. Each plot had 4 rows with 5 m length. There was 1 m space between the plots and 2 m between the blocks. The harvest was made on September 20 in 2013, and in 2014, it was delayed to September 7, due to rainfall in the last week of September. In the harvest, one row from the edges of each plot and 50 cm from each head were evaluated as edge effect and 2 rows in the middle of the plots were harvested. After the harvest, the plants were dried and the seeds were separated by threshing machine.

The two-year data obtained from the research were subjected to variance analysis with JMP 5.0.1 (SAS Institute 2002) package program based on Randomized Complete Block Design. The significant differences between the treatments were compared and grouped according to Duncan Multiple Comparison Test.

3. RESULTS AND DISCUSSION

In this study, the impacts of different row spacing and seeding rates on yield, and yield components and the variance analysis results are given in Table 1.

There was a significant difference ($p < 0.01$) between the years in terms of the examined characters in the study (Table 1). Although the year 2013 was drier and cooler than 2014 and more rainfall was recorded in the second year, the distribution of precipitation was irregular (Table 2). Most probably irregular rainfall and high temperature in 2014 negatively affected the growth of safflower plants.

Table 1. Variance analysis results of yield and yield components of safflower cultivars grown in different row spacings and different planting rate treatments.

Variation Sources	DF	Plant Height (cm)	Brunch Number (no plant^{-1})	Head Numb (cm)	Head Diameter (cm)	Seed Numb. (no plant^{-1})	1000 Seed Weight (g)	Seed Yield (kg ha^{-1})	Seed oil Concentration (g kg^{-1})	Oil Yield (kg ha^{-1})
Year (Y)	1	**	**	**	**	**	**	**	**	**
Cultivar (C)	1	**	**	**	**	**	**	**	**	**
Row spacings (RS)	2	**	**	**	**	**	**	**	**	**
Planting rate (PR)	2	**	**	**	**	**	**	*	*	**
ÇxY	1	**	**	**	ns	ns	**	**	**	ns
ÇxRS	2	**	**	**	ns	**	**	ns	ns	ns
ÇxPR	2	ns	Ns	**	ns	ns	**	ns	ns	ns
YxRS	2	**	**	**	ns	**	**	ns	ns	*
YxPR	2	**	**	ns	**	ns	ns	ns	ns	ns
RSxPR	4	**	*	ns	**	ns	**	ns	ns	ns
CxYxRS	2	**	**	**	**	**	**	**	**	**
YxRSxPR	4	**	Ns	**	ns	**	**	ns	ns	ns
CxRSxPR	4	**	Ns	**	ns	**	**	ns	ns	ns
CxYxPR	2	**	Ns	**	ns	ns	**	ns	ns	ns
CxYxRSxPR	4	**	Ns	Ns	ns	**	ns	ns	ns	ns

In this study conducted under field conditions as a two-year study, except the interaction of cultivar x seeding rate, the effect of all treatments and all other interactions on plant height was significant (Table 1). Plant height was significantly longer in the early year than in the other study year. In both study years, the average plant height of Yenice cultivar was longer than Dinçer cultivar (Table 2). It was determined that the difference between varieties was less in the first study year. The effects of planting rate treatments on plant height have changed according to years and varieties. Due to the increase of row spacings, the plant height has increased. However, this increase was more in the Yenice cultivar (Table 1). In the first year, plant heights at 20 and 40 cm row spacings were very close to each other, while a significant increase was found in the increasing planting distances in the second study year (Table 1). This difference in plant height can probably result from the different climatic conditions in study years. Plant height was higher in the first study year that the rainfall distribution was regular in the growing season, and the reason of the lower plant height in the second study year probably related to irregular rainfall distribution, although rainfall was higher (Figure 1).

Plant height varied significantly in both study years depending on row spacing and planting rate. According to the results in Table 2, the highest plant height was obtained at 60 cm row spacing and 60 kg ha-1 planting rate treatments, and the shortest plant height was obtained from 20 cm sowing width and 20 kg ha-1 seeding rate treatments in both study years. In both years, due to the increasing row spacing and seeding rate, plant height increased, the height was 3.47 cm higher in the second year compared to the first year. The increasing number of plants per unit area decreases the development of side branches and causes the plants to show vertical growth and ultimately the plant to be taller. Sharif Moghaddasi and Omidi (2016) reported that reduced sowing rate will result in reduced competition between plants, development of the root system, and better utilization of nutrients in the soil. Similarly, Uke et al. (2017) stated in their study that plant height values increased in parallel with the increase in plant density and planting rate.

Table 2. The results of plant height, branch number and head number of safflower cultivars grown at different row spacing and olanting rates

Treatments	Plant height (cm)			Branch number			Head number		
	2013	2014	Mean	2013	2014	Ort.	2013	2014	Ort.
Cultivars									
Dinçer	71,3b	55,30b	63.27b	5,08	3,52a	4.28a	6.6a	4.7a	5.7a
Yenice	79,2a	61,40a	70.27 a	5,05	3,08b	4.08b	6.4b	3.5 b	5.0b
Mean	75.2	58.3	66.8	5,07	3,30	4,18	6.5a	4.1b	5.4
Row spacings									
20	74,1c	55,7c	64.9c	4,57c	2,51	3.54c	5.5c	3.7c	4.6c
40	74,2b	58,5b	66.3b	5,01b	2,96	3.98b	6.4b	3.9b	5.2b
60	78,4a	60,9a	69.6a	5,61a	4,44	5.02a	7.6a	4.8a	6.2a
Mean	75.5	58.4	67.0	5,06	3,30	4,20	6.5	4.1	5.3
Planting rate									
2	73,1c	54,7c	63.9c	5,85a	3,61	4.73a	7.1 a	4.7a	5.9a
4	75,1b	58,2b	66.7b	4,94b	3,27	4.10b	6.4b	4.1b	5.3b
6	77,4a	62,2a	69.8a	4,40c	3,03	3.71c	6.1c	3.6c	4.8c
Mean	75.2	58.4	66.8	5,10	3,30	4,20	6.5	4.1	5.3

*Significant at %5' level (P<0.05); **significant at %1 (P<0.01). The difference between the averages shown in different letters is significant.

The number of branches was significantly (p <0.01) affected by all interactions except year, cultivar, row spacing, planting rate treatments and planting rate x cultivar interaction (Table 1). According to the average of the treatments, the number of branches was different in study years, and in the first study year branch number was higher that the rainfall showed a regular distribution. The average branch number of the cultivars varied in study years and branch number was higher in Dinçer cultivar in both study years (Table 2). Varieties reacted differently in terms of the branch number. Depending on the increase in row spacing, the branch number increased in both years, but this increase was more irregular in 2014. This situation, which occurs at row spacings, has also been detected in planting rate treatment. The highest and lowest branch number was determined in the 20 and 60 kg ha-1 seeding rate treatments, respectively. Depending on the increase in the planting rate in each of the row spacing, the branch number decreased and this decrease was more pronounced in the 60 kg ha-1 planting rate. It was observed that the competition between plants decreased due to the decrease in the planting rate and the less plant number per unit area. It was also reported that in lower planting rates, plants receive maximum sunlight for photosynthesis, producing healthy plants, and as a result, the biomass and the branch number of the plants' increase (Oad et al. 2002). Some studies showed that the branch number in lower planting rates or wider rows was high (Amoughein et al. 2012a, Sharif Maghaddasi and Omidi 2016).

The head number per plant, is one of the factors that directly affect the yield, and it was showed difference in study years and cultivars. In the first study year, branch number and head number per plant were higher. The difference between the study years was significant at 1% level (Table 1). The highest head number was obtained from Dinçer cultivar in both study years. The head number of the varieties were varied depending on the years. As the row spacing wider in both cultivars and in study years, the head number increased. In the first year and in the Yenice cultivar there was a significant increase depending on row spacing. Depending on the increase in the planting rate, the number of head decreased, it was the lowest in the 60 kg ha-1 planting rate and the highest in the 20 kg ha-1 seeding rate treatment plots. Increasing seeding rate increases the seed number per unit area and causes a decrease in the branch number. Since the safflower plant forms a head at the top of each branch, the number of the head decreases as the branch number decreases (Weiss 2000). Some researchers reported that the head number decreased due to the increase in the seeding rate (Emami et al. 2011, Sharif Moghaddasi and Omidi 2016, Uke et al. 2017).

In safflower, head diameter is one of the most important yield components. For this reason, it is desired that the head diameter should be large. Head diameter varies depending on the variety, sowing width and planting rate (Naghavi 2012). In our study, the Yenice cultivar had the highest head diameter value (Table 2) and the difference between the cultivars was statistically significant at the p <0.01 level (Table 1). Head diameter values were measured as 1.72 cm in the first study year and 1.57 cm in the second year and this difference was statistically significant (p <0.01) (Table 1). In the first study year, warmer weather and suitable rainfall during the flowering period may have been caused the head diameter to be large. Uslu et al. (2002) reported that the low temperature and humidity during the flowering period, the temperature, and drought in the stem period will cause differences in the head diameter. In our study, head diameter values differed depending on the row spacing and planting rates. It was observed that the head diameter increased due to the increasing of the row spacing. Head diameter values decreased significantly at all row spacing due to the increase in sowing density. The response to the planting rate, depending on the row spacings caused the inter-row x sowing norm interaction to be significant in terms of the head diameter. The reduction of seeding rate decreases the plant number per unit area, decreasing the competition between plants and the plants develop better and the head diameter increases (Sharif Mogdaddasi and Omidi 2016).

According to the variance analysis results, the effect of year, cultivar, row spacing, planting rate treatments, year x row spacing, and row spacing x cultivar interactions on the seed number per head was significant (Table 1). The highest seed number per head was obtained in the first study year, and it showed variation in the cultivars (Table 3). The highest seed number per head was determined in the Dinçer cultivar. Due to the differences arising from the genetic structure of safflower varieties grown under the same ecological conditions, the seed number per head may differ. As a matter of fact, this situation was demonstrated in previous studies (Çalıskan and Çalıskan 2018). In this study, the highest seed number per head was obtained from 60 cm row spacings, it was the same in both study years. The seed number increased depending on the increase in the row spacings. The fact that the response of the safflower plant to the row spacing was different in study years caused the year x row spacing to be significant. The increases in the planting rates caused a significant change in the seed number per head, and the seed number per head was higher in 20 kg ha-1 treatments (Table 3). Depending on the increase in row spacings, the seed number per head increased in both varieties, but this increase was more pronounced in the Yenice cultivar (Table 3). That high plant density decreases the number of seed per plant by increasing water consumption and causing water deficiency in the post-flowering period.

Table 3. The results of table diameter, head number per plant, seed number per head and 1000 seed weight of safflower cultivars grown at different row spacing and planting rates

Treatments	Head diameter (cm)			Seed number per head			1000 seed weight (g)		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Dinçer	1.70b	1.55b	1.60 b	23.9a	22.1a	23.0a	44.8a	39.2a	42.0a
Yenice	1.73a	1.59a	1.66a	22.1b	20.2	22.2b	41.6b	31.2b	36.4b
Mean	1.72	1.57	1.63	23.0	21.2	22.6	43.2	35.2	39.2
Row spacings									
20	1.65c	1.52c	1.58c	21.6b	20.1c	20.9c	41.2b	33.8c	37.5c
40	1.73b	1.56b	1.64b	23.5a	20.8b	22.2b	44.2a	35.2b	39.7b
60	1.77a	1.63a	1.70a	23.9a	22.4a	23.1a	44.4a	36.6a	40.5a
Mean	1.72	1.57	1.64	23.0	21.1	22.1	43.3	35.2	39.2
Planting rates									
2	1.78	1.68a	1.73a	23.9a	22.1a	23.0a	44.3a	36.2a	40.3a
4	1.74	1.56b	1.63b	22.9b	20.8b	21.9b	42.8b	35.1b	38.9b
6	1.68	1.47c	1.57c	22.1c	20.5b	21.3c	42.7b	34.4c	38.5c
Mean	1.73	1.57	1.64	23.0	21.1	22.1	41.4	35.2	39.2

*Significant at %5' level (P<0.05); **significant at %1 (P<0.01). The difference between the averages shown in different letters is significant.

In this study, except for the year x planting rate interaction, all treatments and interactions had a significant effect on 1000-seed weight, which is an important yield factor (Table 1). The average 1000 seed weight was 43.2 g and 35.2 g in 2013 and 2014, respectively (Table 3). Seed weight is an important character directly related to climatic conditions, especially during the flowering period. In the second study year, in the first week of August, the flowering period of the plant, there was almost no rainfall and high temperature may have caused the seed weight to be lower. In both years, the highest seed weight was obtained from Dinçer cultivar. Beyyavas et al. (2011) reported that genotype and ecological conditions are two important factors affecting 1000 seed weight. In 2014, the seed weight of Yenice cultivar was lower than Dinçer. (Table 3). This situation may have resulted from plant competition to climatic factors that positively affect seed development during the seed filling stage. The lowest 1000 seed weight was obtained in 20 cm row spacing (37.5 g), the highest 1000 seed weight was obtained from 60 cm row spacing treatments. As a result of the increase in the planting distance in both varieties, the 1000 seed weight increased, but this increase was higher in Dinçer than Yenice cultivar. As a result of the less plant competition in the widening of rows, it is expected that the head diameter and seed were larger. The seed weight varied depending on the seeding rates. In our study, it was determined that the seed weight in the treatment of 60 kg ha-1 plantings was lower than other seeding rates. Due to the increase of plant competition in higher planting rates, the development of the photosynthesis organs and other metabolic activities are slow. This negatively affects the seed development especially during the seed forming period, and accordingly, the seed weight decreases with the increase in the planting rates (Zarei et al. 2011, Emami et al. 2011, Çalıskan and Çalıskan 2018).

Table 4. The results of seed yield, seed oil concentration and oil yield of safflower cultivars grown at different row spacing and planting rates

Treatments	Seed yield (kg ha^{-1})			Seed oil concentration (g kg^{-1})			Oil yield (kg ha^{-1})		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Cultivars									
Dinçer	870.0a	780.6a	820.8a	200.6a	180.7	190.7a	170.9a	140.7a	160.3a
Yenice	810.5b	680.5b	750.0b	190.5b	180.3	180.9b	150.9b	120.5b	140.2b
Mean	840.3	730.6	780.9	200.1	180.5	190.3	106.9	130.6	150.3
Row spacings									
20	860.4a	720.0b	790.2b	200.0	180.1b	1900.1b	170.3a	130.1b	150.2b
40	840.7a	780.0a	801.4a	200.6	190.3a	200.0a	170.5a	150.0a	160.3a
60	810.7b	710.0b	760.2c	190.5	180.2b	180.9b	150.9b	120.9b	140.4c
Mean	840.3	730.7	780.9	200.0	180.5	190.3	160.9	130.7	150.3
Planting rates									
2	810.0c	680.5c	740.8c	200.3	180.8	190.6a	160.4	120.9b	140.7
4	830.8b	730.3b	780.6b	200.2	180.4	190.3ab	160.9	130.5b	150.2
6	880.0a	780.9a	830.5a	190.6	180.3	190.0b	170.3	140.5a	150.9
Mean	840.3	730.6	790.0	200.0	180.5	190.3	160.9	130.6	150.3

*Significant at %5' level ($P<0.05$); **significant at %1 ($P<0.01$). The difference between the averages shown in different letters is significant.

Year, cultivar, row spacing and seeding rate effects were significant on seed yield, which is the main purpose in growing for this plant. Also, the effect of all interaction sources was found to be insignificant, except for the cultivar x year interaction (Table 1). According to the average of the study years and treatments, the seed yield was determined as 820.8 ha-1 in Dinçer cultivar and 750.0 kg ha-1 in Yenice. Dinçer cultivar had higher seed yield than Yenice in both study years. The seed yield in the first year was approximately 100.0 kg ha-1 higher than the second year (Table 4). However, the difference between varieties in terms of seed yield significantly higher in the second year. The higher seed yield in 2013 compared to 2014 can be explained by the more suitable climatic factors in the 2013 growing season. The total precipitation amount, during the plant growth period, was 60.4 mm and 153.1 mm in 2013 and 2014, respectively. During the stemming (June), flowering (July), and seed filling period (August), regular rainfall and the suitable temperature positively affected the branch number, the head number, the seed number per head, and the 1000 seed weight that the seed yield is directly affected by these characteristics. It is well known that there may be significant differences in seed yield between safflower varieties (Bella et al. 2019). According to the average of the experimental factors, seed yield increased up to 40 cm and decreased to 60 cm row spacing (Table 4). The seed yields of the safflower plant in the 20, 40 and 60 cm row spacing were determined as 790.2, 810.4 and 760.2 kg ha-1, respectively (Table 4). It is understood that with the increase of the row distance, the head number per plant, the seed number per head and the 1000 seed weight increased and the seed yield increased accordingly. The seeding rate has a direct effect on the seed yield. For this reason, it is highly important to examine the effect of different planting rate treatments. In the study, the seed yield increased due to the increase in sowing rates, and it was determined as 740.4 kg ha-1 at 20 kg ha-1 seeding rate, 780.6 kg ha-1 at 40 kg seeding rate, and 830.4 kg ha-1 at 60 kg ha-1 seeding rate. Ahadi et al. (2011) stated that the seed yield increased by increasing seeding rates, Berglund et al. (1998), Zarei et al. (2011) stated that the plants grown in wide seeding distances utilize more from sunlight, and the seed yield increased due to the decrease in competition.

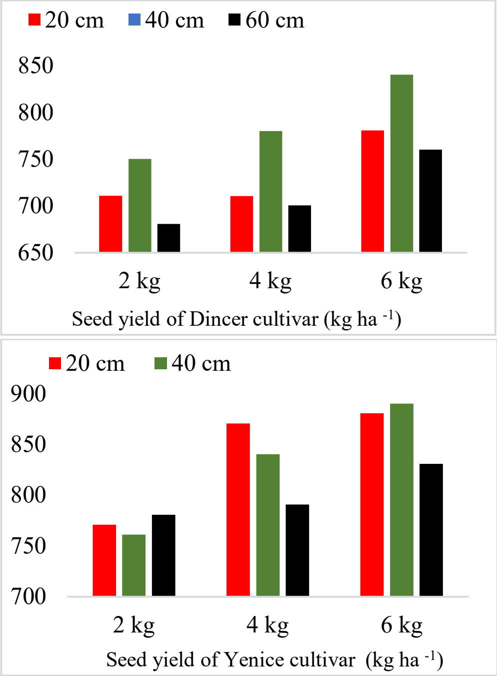

Figure 2. Average seed yield of Dinçer and Yenice safflower cultivars

Safflower is mainly grown for oil production. The seed oil concentration in safflower varied depending on the varieties and the highest seed oil concentration was obtained from Dinçer cultivar (190.7 g kg-1). The seed oil concentration was determined as 200.0 g kg-1 in 2013 and 180.5 g kg-1 in 2014 (Table 4). This difference between the study years in terms of seed oil concentration was statistically significant (p <0.01) (Table 1). The differences observed in seed oil concentration were probably related to temperature and soil moisture content during the seed filling period. It was stated that the seed oil concentration is significantly affected by the temperature differences and the seed oil concentration decreases during the warmer weather conditions in the seed filling period (Weiss 1983). Dinçer cultivar had higher seed oil concentration in both research years. The seed oil concentration was determined as 190.04, 190.92 and 180.85 g kg-1 at 20, 40 and 60 cm planting distances, respectively, and the response of the seed oil concentration to the planting distances was irregular. In this study, the lowest seed oil concentration (180.98 g kg-1) was obtained from the 60 kg ha-1 planting rate and the highest (19.55 g kg-1) from the 20 kg ha-1 planting. The decrease in the seed oil concentration by the effects of the increase in the planting rates can be explained by the increase in plant competition for environmental factors such as mineral substances, water, and sunlight. In some studies carried out on the same subject, it was reported that the increase in plant density decreases the seed oil concentration (Amoughein et al. 2012b, Calıskan and Calıskan 2018).

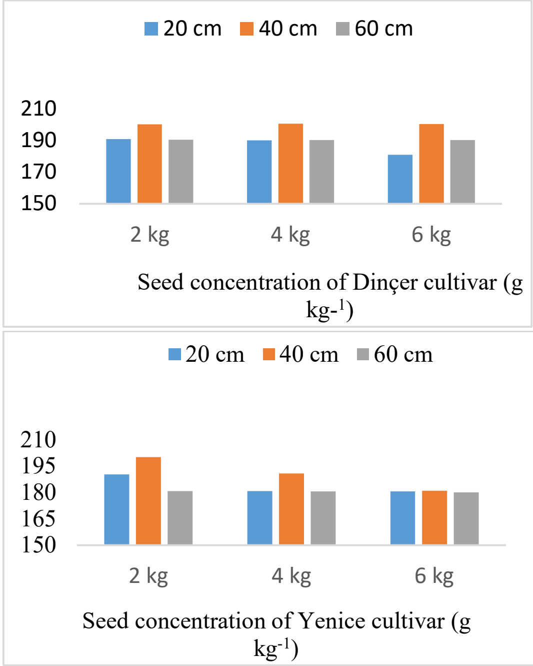

Figure 3. Average oil content of Dinçer and Yenice safflower cultivars

The effect of all treatments on oil yield, which is a result of seed yield and seed oil concentration, was significant, and all interactions were insignificant, except for the year x row spacing. In the research, the highest seed oil concentration was obtained from Dinçer cultivar (Table 2). This is due to the seed oil concentration and seed yield of Dinçer cultivar were higher than Yenice. seed oil concentration in the first study year (16.9 kg ha-1) was higher than in the second year (13.6 kg ha-1). Irregular rainfall in the second year and warmer weather conditions in the post-flowering period caused a decrease in the seed yield and thus the oil yield. It was determined that the increase of row spacing, the oil yield increased up to a certain width and then decreased. As a result of our research, it was determined that the oil yield increased until the row distance of 40 cm and then (60 cm) the oil yield decreased. Due to the increase in the planting rates in safflower, the oil yield increased and the highest oil yield was obtained at 60 kg ha-1 plantings. Especially seed yield and seed oil concentration values are directly effective in this situation. Studies were reported that the main reason is seed yield for the high oil yield (Shahri et al. 2013, Vagdar et al. 2014).

4. CONCLUSION

In this study, depending on the increase in-row spacing, plant height, stem diameter, 1000 seed weight, branch number, head diameter, and seed number per head increased. The increase of row spacing from 20 to 40 cm, seed oil concentration, seed and oil yield significantly increased, while increasing it from 40 to 60 cm caused a serious decrease in seed oil content, seed, and oil yield. The increase in the planting rate significantly decreased the seed oil concentration, the seed number per head, the head number, 1000 seed weight, stem diameter, branch number, and head diameter. In safflower production in dry farming areas, the yields of varieties may differ depending on high seed and oil yield, and therefore it is important to choose the appropriate cultivar for the region. In this study, the seed yield and oil ratio values were low due to the study was carried out in dry conditions, short growing season, low rainfall and temperatures, high altitude. It is important to research for more years in order to obtain healthy results, especially to evaluate the reaction of the safflower plant by years. As a result of this research, the fact that the highest yield was obtained at 20 and 40 cm row spacing and 60 kg ha-1 seeding rate supports that high yield can be obtained from frequent planting. In addition, the sowing distance of 20 cm will allow safflower cultivation to be done using grain drill, it will provide equipment savings and convenience in agricultural enterprises.

As a result, in semi-arid climates dominated by continental climatic conditions with short vegetation period, high planting rate, narrow row spacing are required in terms of yield and yield components for small-grained plants such as safflower in dry conditions.

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