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Araştırma Makalesi (Research Article)

The Influence of Row Spacing and Seeding Rate on Yield and Yield Components of Safflower (*Carthamus tinctorius* L.)

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Abstract

In safflower production, yield is affected row spacing, seeding rate and varieties give different response to them. For this reason, determining the optimum row spacing and seeding rate for each variety is important to obtain high yields and quality. In this research was conducted to determine the effect of row spacing and seeding rate on yield and quality traits of Balci safflower (*Carthamus tinctorius* L.) variety registrated in 2011. The experiment was conducted at the Transitional Zone Agricultural Research Institute, Eskisehir, Türkiye using a randomized complete block split-plot design with four replicates in 2012, 2013 and 2014 growing seasons. Three different row spacing (15, 30 and 45 cm) and five different seeding rates (15, 30, 45, 60 and 75 kg ha^{-1}) were used in experiments. Seed yield, oil content, oil yield, the number of branches per plant, the number of seed per head and 1000 seed weight were investigated in this research. As a result of this study significant effect on seed and oil yield was determined in terms of row spacing and seeding rate. It was recommended that Balci safflower variety should be sown with 30 or 45 cm row spacing with 45 kg ha^{-1} seeding rate to obtain the highest seed and oil yield. Especially, safflower production areas where temperature and humidity is too high to reduce the development of diseases and provide mechanical weed control 45 cm row spacing with 45 kg ha^{-1} seeding rate should be used for production

Keywords: Safflower, row spacing, seeding rate, yield

Aspir (*Carthamus tinctorius* L.) Bitkisinde Sıra Arası Mesafe ve Ekim Normunun Verim ve Verim Unsurları Üzerine Etkisi

Öz

Aspir üretiminde verim, sıra arası mesafe ve ekim normu uygulamalarından etkilenmekte olup çeşitlerin bu uygulamalara reaksiyonları farklıdır. Bu nedenle, her çeşit için uygun sıra arası mesafe ve ekim oranının belirlenmesi yüksek verim ve kalite açısından önem taşımaktadır. Bu çalışma, 2011 yılında tescil ettirilen Balcı aspir çeşidi için en uygun sıra arası mesafe ve ekim normunu belirlemek amacı ile yürütülmüştür. Deneme; 2012, 2013 ve 2014 yıllarında, Eskişehir Geçit Kuşağı Tarımsal Araştırma Enstitüsü deneme tarlalarında tesadüf blokları bölünmüş parseller deneme desenine uygun olarak 4 tekerrür halinde ekilmiştir. Çalışmada 3 farklı sıra arası mesafe (15, 30 ve 45 cm) ve 5 ekim normu (15, 30, 45, 60 ve 75 kg ha^{-1}) kullanılmıştır. Çalışmada tane verimi, yağ oranı, yağ verimi, bitkide dal sayısı, tablada tane sayısı ve 1000 tane ağırlığı değerleri incelenmiş olup, sıra arası ve ekim normu uygulamaları tane ve yağ verimi üzerine farklı etkilerde bulunmuştur. Buna göre; Balcı aspir çeşidi için 30 veya 45 cm sıra arası mesafe ile 45 kg ha^{-1} ekim normu uygulamalarının en yüksek tohum ve yağ verimi elde etmede uygun olduğu tespit edilmiştir.Özellikle, sıcaklığın ve nemin yüksek olduğu aspir üretim alanlarında hastalık gelişimini azaltmak ve mekanik ot kontrolünü sağlamak için 45 cm sıra arası mesafe ile 45 kg ha^{-1} ekim normunun kullanılmalıdır.

Anahtar Kelimeler: Aspir, ekim normu, sıra arası mesafe, verim

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Introduction

Safflower has a wide adaptation and more drought and salt resistance than other oil seed plants. Therefore it can be grown successfully in arid areas (El-Lattief 2012;Omidi et al. 2012). In recent years, safflower has received great attention for its biodiesel production in dryland regions (Bergman and Charles 2008; Sujatha 2008). In Türkiye, safflower seed production has increased nearly three times in the last five years and it reached 62.000 tons in 2014 (Anonymous 2016).

Safflower row spacing and seeding rates attach to environment condition, production systems and vary considerably in the world (Mündel et al. 1994). Several field trials indicated that row spacing and seeding rate has significantly affected safflower seed and oil yield. In California, 15–20 cm row spacing produces lower yields than 30-60 cm spacing. Weiss (2000) found that 15–23 cm row spacing give the highest yields in Nebraska. Esendal (1986) determined that the seed yield of safflower increased appreciably as the row distance was decreased from 90 to 18 cm. The highest seed yield obtained from 18 cm rows in Erzurum Valley. Mündel et al. (1994) found that seed yield was maximized at 23 cm row spacing and 32-40 kg ha^{-1} seeding rate in southern Alberta. Herdrich (2001) obtained that seed rate of 20 kg ha^{-1} was to be optimal in the Washington State of USA. In the Bekaa Valley of Lebanon, the seed rate of 24 kg ha^{-1} was detected to be ideal for seed production in semi-arid areas (Yau 2009). In Iran, row spacing greatly affected seed yield and 15 cm row spacing was recommended by Mohammadi and Karimizadeh (2013).

Some researchers emphasized that genotype gave different reaction to row spacing and seeding rate (Salerea 1997; Omidi 2000; Özel et al. 2004; Omidi et al. 2009; Mohamadzadeh et al. 2011; Sharif Moghaddasi and Omidi 2016).Therefore, identifying the optimum row spacing and seeding rate for each genotype are important to obtain safflowers with high yields and quality.

Very limited information about the optimum row spacing and seeding rate is presently available in safflower production particularly under dryland conditions with Balci safflower variety registrated in 2011. In this study aimed to investigate the effects of row spacing and seeding rates on seed yield, oil yield and some yield components of Balci safflower variety under dryland conditions.

Material and Method

Field experiments were conducted at the Transitional Zone Agricultural Research Institute (39°45''57' N, 30°24'' 5' E) in Eskisehir, Turkey in 2012, 2013 and 2014 growing seasons. The soil was a clay loam, 1120 kg ha^{-1} potassium and 91 kg ha^{-1} phosphorus and poor in organic matter (1.2%) and slightly alkaline (pH= 7.2).

The climate of location was characterized as typical continental climate with cold winters, hot and dry summers and winter and early spring precipitation. The long-term (1928-2014), total annual precipitation was 300 mm, annual mean temperature was 15°C, and average relative humidity was 50%. Temperature, rainfall and relative humidity during the experimental period (March – August) are shown in Table 1.

The field experiments were performed under rainfed conditions and cv. Balci was used as a plant material. This variety was developed in the Transitional Zone Agricultural Research Institute. The experiment was a randomized complete block design in a split plot arrangement with four replications. The main plot was row spacings (15, 30 and 45 cm) and subplot was seeding rates (15, 30, 45, 60 and 75 kg ha^{-1}). The individual plot size was 1.8 m x 10 m = 18 m^2. Seeding was made in the first week of March in every year by hand, at a double / triple rate. Manual thinning was used to obtain the required plant number per square meter after emergence.80 kg ha^{-1} nitrogen (33% ammonium nitrate) and 60 kg ha^{-1} phosphorus (superphosphate) were applied at seeding stage. Weeds were controlled by hand during growing season.

The plots were harvested at full maturity in August. Before harvesting, 15 plants were sampled from each individual plot and measured by the number of branches per plant, the number of seed per head and 1000 seeds weight. The interior rows in each plot (six 15 cm rows, three 30 cm rows and two 45 cm rows) were harvested by hand and threshed with a Hege plot combine harvester for seed yield. The oil content was determined using Soxhlet extraction apparatus. Oil yield

Table 1. Monthly and growing season lowest, highest and mean temperature, relative humidity and rainfallin 2012, 2013 and 2014

Çizelge 1. 2012, 2013 ve 2014 yıllarına ait büyüme sezonu ve aylara göre en düşük, en yüksek ve ortalama sıcaklık, nispi nem ve yağış miktarı

	Lowest temperature (°C)	Highest temperature (°C)	Mean temperature (°C)	Relativ humidity (%)	Rainfall (mm)
Mounts			Long Term (1965-2014)		
March	-9.1	22.1	4.8	62.2	33.6
April	-4.4	26.4	10.1	59.4	44.0
May	0.2	29.7	14.8	56.6	44.4
June	4.1	33.4	18.5	53.5	25.1
July	7.3	35.8	21.4	52.9	10.0
Agust	6.7	34.7	21.0	52.4	9.6
Mean	0.9	30.5	15.1	56.3	-
Total	-	-	-	-	166.7
Year			2012		
March	-13.2	16.3	1.5	87.7	56.4
April	-4.5	26.9	12.0	72.6	22.1
May	4.9	26.9	14.4	83.3	80.9
June	5.8	34.2	20.0	71.6	0
July	8.3	37.2	22.8	68.1	5.5
Agust	5.4	34.6	20.8	65.1	3.5
Mean	1.1	29.6	15.3	74.7	-
Total	-	-	-	-	168.4
Year			2013		
March	-9.2	21.8	7.1	59.8	33.2
April	0.2	28.4	10.8	63.2	37.8
May	6.2	31.6	17.7	51.5	9.5
June	5.8	35.1	20.0	53.1	14.0
July	8.8	38.5	23.7	50.6	0.8
Agust	11.2	34.8	22.4	53.1	0
Mean	3.8	31.5	17.0	55.2	-
Total	-	-	-	-	95.3
Year			2014		
March	-5.9	23.0	6.2	69.0	27.1
April	-3.7	26.6	11.3	63.7	23.2
May	6.6	28.5	16.4	63.3	53.8
June	8.9	35.4	19.9	64.1	70.5
July	13.6	34.0	21.6	57.8	20.4
Agust	15.4	36.4	24.1	58.9	12.2
Mean	5.8	30.6	16.6	62.8	-
Total	-	-	-	-	207.2

was calculated by multiplying the oil content and the seed yield of each individual plot.

Bartlett's test was used to determine the homogenity of variances between years before analysis of variance. All data was subjected to analysis of variance for each character using the statistical package JMP 5.0.1 (SAS, 1989 - 2002). Statistically significant differences among the mean values were determined with the least significant difference (LSD) test at the 0.05 level.

Results and Discussion

According to Bartlett’s homogenity test, three years’ data were used combined to analyze the variance and mean comparisons. According to the data combined over three years, differences between effects of years were statistically significant for all characters. The influence of row spacing, seeding rate, row spacing x seeding rate, year x row spacing, year x seeding rate and year x row spacing x seeding rate interactions on studied characteristics are presented in Table 2.

Not only some features of safflower genotypes are controlled genetic factors, but they are also influenced by different agronomic applications and environmental conditions. Therefore, to achieve the highest yield from safflower determining a suitable row spacing and seeding rate is too important for production.

According to years while the highest seed yield (2142.4 kg ha^{-1}) was determined in the 2014 growing season, the lowest seed yield (1240.8 kg ha^{-1}) was obtained in the second year of the study like the other studied characteristics (Table 1). The main reason for this difference was the distinction among climatic conditions of growing seasons. During 2013, the lowest amount of rainfall was received than the other years. Especially, because of the insufficient rainfall after April and high temperatures probably reduced the seed yield.

In this research, differences of row spacing and seeding rate had important effects on seed yield of safflower. The highest seed yield (1997.1 kg ha^{-1}) was determined in 30 cm row spacing, the lowest seed yield (1451.9 kg ha^{-1}) was found from the narrowest row spacing (15 cm) treatment. Similarly, Öztürk et al. (1999) and Kızıl et al. (1999) stated that the highest seed yield was determined in 30 cm row spacing treatment. Similar findings were also reported by Uslu et al. (1997) and Sharif Moghaddasi and Omidi (2016). Our results are in close agreement with those experiments given above. When Table 3 is examined it is clear that above or below of 45 kg ha^{-1} seeding rates had decreased seed yield in this study. Yau (2009) recommended 24 kg ha^{-1} seeding rate on seed yield to obtain the highest seed yield in arid conditions. Since seed yield is determined by several environmental factors (climatic factors and soil 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. The Influence of row spacing x seeding rate interaction on seed yield was also found to be important. In this situation shows the interactions between row spacing and seeding rate. The highest seed yields (2366.4 kg ha^{-1}) was determined at 30 cm row spacing with 45 kg ha^{-1} seeding rates and followed by 45 cm x 45 kg ha^{-1} (2219.3 kg ha^{-1}) treatment had same statistical group. In terms of seed yields 15 cm x 75 kg ha^{-1} (1168.5 kg ha^{-1}) and 15 cm x 15 kg ha^{-1} (1176.1 kg ha^{-1}) treatments seemed to be low (Table 4).

Table 2. Variance analysis
Çizelge 2. Varyans analizi

Source	Degree of fredoom	Seed yield	Oil content	Oil yield	Number of branch per plant	Number of seed per head	1000 seed weight
Years (Y)	2	**	**	**	**	**	**
Bloks	9	*	ns	*	*	ns	ns
Row Spacing (RS)	2	**	ns	**	**	**	ns
Y x RS	4	**	**	**	ns	ns	ns
Error (a)	18	**	**	**	**	**	ns
Seeding Rate (SR)	4	**	**	**	**	**	ns
RS x SR	8	**	ns	**	**	**	ns
Y x SR	8	ns	ns	ns	ns	**	ns
Y x RS x SR	16	**	**	**	ns	**	ns
Error (b)	108						

*, **: Significant at p<0.05 and 0.01, respectively. ns: not significant

**, **: Sırasıyla, p<0.05 ve 0.01 seviyesinde önemli. ns: önemli değil*

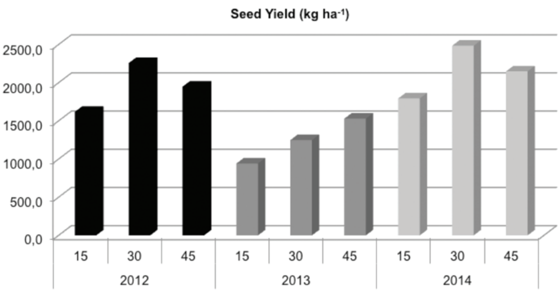

Figure 1.Row spacing x year interaction on seed yield

Şekil 1. Tane verimi üzerine sıra arası yıl interaksiyonu

With regard to row spacing x seeding rate interaction, oil yields of 30 cm x 45 kg ha^{-1} (906.8 kg ha^{-1}) and 45 cm x 45 kg ha^{-1} (851.1 kg ha^{-1}) treatments seemed to be high (Table 4).

In this study, row spacing x year was also significant on the seed yield. As seen in Figure 1, the highest seed yields were determined from 30 cm row spacing in 2012 (2257.2 kg ha^{-1}) and 2014 (2484.5 kg ha^{-1}), from 45 cm row spacing in 2013 (1529.9 kg ha^{-1}). The second year of this research was conducted in the most arid condition in this experiment (Table 1). Sing and Yusuf (1981) reported that using wider row spacing gave better results in case of the moisture content of the soil being insufficient. These findings imply that safflower should be planted in wide row spacing under the arid conditions. Some researchers conducted their research in arid conditions and emphasized similar results in their experiments (Umrani and Bhoi 1984; Sharif Moghaddasi and Omidi 2016; Hamza 2015).

The oil content is an important factor affecting the success of safflower production. In this study while the effects of row spacing, row spacing x seeding rate on oil content were not significant, seeding rate had significant effects on oil content Similar results were released by Gonzalez et al. (1994) and Yau (2009). Seeding rates of 45 kg ha^{-1} (37.8%) and 60 kg ha^{-1} (37.7%) also had higher oil content than other treatments (Table 3). These findings mean that genotype is the most important factor for oil content. As indicated in previous studies, the oil content of safflower mostly depends more on the genotype than the agronomic application and environment condition (Rahamatalla et al. 2001; Jajarmi et al. 2008). The oil yield was calculated on the seed yield, oil content and related to them. In this study the highest oil yields were determined in 2014 (809.8 kg ha^{-1}) similar to seed yield (Table 3).The reason is that experimental location had high rainfall during the growing period of safflower than the other years. Distribution of rainfall is as important as the amount of rainfall. Agasimani et al. (1997) emphasized that yield

Table 3. Effects of years, row spacing and seeding rate on seed yield, oil content, oil yield, number of branch per plant, number of seed per head and 1000 seed weight (average of 3 years)[1]

Çizelge 3. Yıl, sıra arası mesafe ve ekim normu oranının tane verimi, yağ oranı, bitkide dal sayısı, tablada tane sayısı ve 1000 tane ağırlığı üzerine etkisi (3 yıl ortalaması)[1]

Years	Seed yield (kg ha^{-1})		Oil content (%)		Oil yield (kg ha^{-1})		Number of branch per plant		Number of seed per head		1000 seed weight (g)	
2012	1941.6	b	38.1	a	741.4	b	5.53	b	11.5	a	38.3	a
2013	1240.8	c	35.4	b	442.1	c	3.85	c	9.9	c	36.0	b
2014	2142.4	a	37.8	a	809.8	a	7.72	a	11.0	b	37.7	a
LSD (0.05)	6.92		0.52		2.64		0.27		0.21		1.69	
Row Spacing (cm)												
15	1451.9	b	37.2		544.6	c	5.1	c	10.0	c	37.8	
30	1997.1	a	37.1		750.3	a	6.1	a	11.6	a	37.5	
45	1875.9	c	37.1		698.3	b	5.8	b	10.9	b	36.6	
LSD (0.05)	6.92		ns		2.64		0.24		0.21		ns	
Seeding Rates (kg ha^{-1})												
15	1449.9	d	36.4	b	532.7	d	6.1	b	10.2	d	37.2	
30	1740.5	c	36.9	b	645.2	c	6.9	a	10.6	c	38.0	
45	2134.1	a	37.8	a	813.7	a	5.7	c	11.8	a	37.9	
60	1885.1	b	37.7	a	713.7	b	5.1	d	10.9	b	36.8	
75	1664.9	c	36.7	b	616.8	c	4.8	e	10.7	c	36.1	
LSD (0.05)	9.5		0.58		3.75		0.28		0.19		ns	

[1]Means of the same column followed by the same letters were not significantly different at p<0.05 level using LSD test

[1]LSD testine göre aynı sütunda yer alan ortalamaları takip eden aynı harfler p<0.05 düzeyde anlamlı farklılık göstermemektedir

Table 4. Row spacing and seeding rate interactions on seed yield, oil content, oil yield, number of branch per plant, number of seed per head and 1000 seed weight (average of 3 years)[1]

Çizelge 4. Tane verimi, yağ oranı,yağ verimi, bitkide dal sayısı, tablada tane sayısı ve 1000 tane ağırlığı üzerine sıra arası mesafe ve ekim normu interaksiyonlarının etkisi (3 yıl ortalaması)[1]

Row spacing (cm)	Seeding rates (kg ha^{-1})	Seed yield (kg ha^{-1})	Oil content (%)	Oil yield (kg ha^{-1})	Number of branch per plant	Number of seed per head	1000 seed weight (g)
15	15	1176.1 g	37.1	439.1 g	5.7 e	9.5	36.3
	30	1377.8 f	36.6	508.5 f	6.2 b	9.7	37.6
	45	1816.7 c-e	37.2	683.3 c-e	5.1 c	10.8	39.2
	60	1720.3 e	38.2	657.5 de	4.4 f	10.0	39.2
	75	1168.5 g	36.7	434.8 g	4.2 f	10.0	34.6
30	15	1747.7 de	35.9	643.4 e	6.4 b	11.0	37.9
	30	1986.5 b	37.3	742.3 bc	6.4 b	11.5	38.4
	45	2366.4 a	37.9	906.8 a	6.3 b	12.7	37.4
	60	1998.1 b	37.3	755.4 b	5.7 cd	11.7	36.4
	75	1886.6 b-d	36.8	703.9 b-e	5.6 cd	11.3	37.6
45	15	1426.0 f	36.2	515.5 f	6.3 b	10.1	37.4
	30	1857.3 b-e	36.7	684.7 c-e	7.4 a	10.7	37.9
	45	2219.3 a	38.3	851.1 a	5.7 c	11.9	37.0
	60	1937.1 bc	37.5	728.3 bc	5.1 de	11.0	36.7
	75	1939.7 bc	36.6	711.8 b-d	4.5 f	10.7	36.0
LSD (0.05)	16.5	ns	6.32	0.41	ns	ns	

[1]Means of the same column followed by the same letters were not significantly different at $p<0.05$ level using LSD test

[1]LSD testine göre aynı sütunda yer alan ortalamaları takip eden aynı harfler $p<0.05$ düzeyde anlamlı farklılık göstermemektedir

was significantly influenced by rain, particularly during the early stages of safflower. The effects of different row spacing, seeding rates and row spacing x seeding rate interactions on oil yield were found to be important.

Similar to seed yield the highest oil yield was determined in 30 cm row spacing (750.3 kg ha^{-1}) and also 45 kg ha^{-1} seeding rate (813.7 kg ha^{-1}). Oil yield was significantly affected by the interaction of row spacing and seeding rate. Similar to seed yields, the increasing seeding rates increased oil yields (Table 3). On the other hand, such increases above the seeding rate of 45 kg ha^{-1} did not result in yield increases. With regard to row spacing x seeding rate interaction, oil yields of 30 cm x 45 kg ha^{-1} (906.8 kg ha^{-1}) and 45 cm x 45 kg ha^{-1} (851.1 kg ha^{-1}) treatments seemed to be high (Table 4). This result revealed that the increase of oil yield was primarily associated with the increase of seed yield.

Different row spacing and seeding rate had significant effects on the number of branches and the number of seed per head (Table 2). The highest number of branches and the number of seed per head were observed at 30 cm row spacing (6.1 and 11.6, respectively). The lowest number of branches per plant and the number of seed per head were obtained from the narrowest row spacing treatment. Seeding rate of 30 kg ha^{-1} had highest number of branches per plant and increasing seeding rate decreased the number of branches per plant (Table 3). Sharif Moghaddasi and Omidi (2016) and Amoughin et al. (2012) reported that increasing the seeding rate may be the main cause to decrease light intensity around plants and diminished branching. Considering row spacing and seeding rate together, 45 cm x 30 kg ha^{-1} treatment had the highest number of branches per plant. While the highest numbers of seed per head was determined 30 cm row spacing and 45 kg ha^{-1} seeding rate, the lowest value was obtained 15 cm row spacing and 15 kg ha^{-1} seeding rate. When the effect of the year was examined on the number of seed per head the lowest value was determined in 2013 (Table 4). This may be the result of increasing temperatures and low rainfall during the flowering period especially in July (Table 1) leading to reducing the number of seed per head.

The effects of row spacing, seeding rate, row spacing x seeding rate interactions on 1000 seed weight Balci variety were not found to be significant. 1000 seed weight of row spacing treatments varied between 36.6-37.8 g (45-15 cm) and ratios of seeding rate treatments varied between 36.1-38.0 g (75-30 kg ha^{-1}) (Table 3). Beyyavas et al. (2011) reported that the genotype and ecological condition were two important factors, which were effective on 1000 seed weight. Our findings showed that differences of 1000 seed weight may have been a consequence of the genetically structure of the genotype especially. The lowest 1000 seed weight (34.6 g) were determined at 15 cm row spacing with 75 kg ha^{-1} seeding rates, although the differences between them were not significant (Table 4). This was the result of interplant competition negatively affecting seed development during the seed filling stage.

Conclusions

According to this experiment results, row spacing and seeding rate were important factors to be noted in the cultivation of safflower production. The majority of farmers in large safflower producing area use narrow row spacing (13-15 cm) predominately in Turkey. Theoretically, wider row spacing would allow more air movement within the crop, thus minimizing damage because of the Alternaria leaf spot disease. In the present study, regarding the row spacing x seeding rate interaction, 30 or 45 cm row spacing with 45 kg ha^{-1} seeding rate was suggested for seed and oil yield of Balci safflower variety. Increasing row spacing provides more favorable conditions for the development of plants and can be advantageous in terms of air circulation among plants, especially hot and humid regions. Safflower production areas where temperature and humidity is too high to reduce the development of diseases 45 cm row spacing with 45 kg ha^{-1} seeding rate should be used for production. Besides these, using 45 cm row spacing can also provide the mechanical weed control safflower needs in the production area.

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