THE EFFECTS OF NITROGEN AND ZINC APPLICATIONS ON THE YIELD, YIELD COMPONENTS AND OIL RATIO OF SAFFLOWER (*Carthamus tinctorius* L.) UNDER SEMI-ARID CONDITIONS

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Abstract. This study was conducted in order to determine the effect of Nitrogen (N) and Zinc (Zn) on the yield, yield components and oil ratio of safflower under semi-arid conditions in 2011-2012 and 2012-2013 growing seasons. Field trials was established in the randomized complete blocks design split plots with three replications in the experimental area Department of Field Crops of Agricultural Faculty, Harran University in Turkey. In the study, N applications (N_0 = no fertilization, N_5 = 50 kg ha^{-1}, N_{10} = 100 kg ha^{-1} and N_{15} = 150 kg ha^{-1}) were placed in the main plots, Zn applications (Zn_0 = no fertilization, Zn_1 = 10 kg ha^{-1}, Zn_2 = 20 kg ha^{-1} and Zn_3 = 30 kg ha^{-1}) were in the sub-plots. Seed yield (kg ha^{-1}), seed yield per plant (g plant^{-1}), plant height (cm), number of heads per plant (pieces plant^{-1}), number of seeds per head (pieces head^{-1}), 1000 seeds weight (g), dry petal yield (g plant^{-1}), oil ratio (%) and biomass yield (kg ha^{-1}) were examined in the study. The results indicated that; the highest seed yields were obtained from the N_{15} (1171 and 1651 kg ha^{-1}) and Zn_3 (1233 and 1675 kg ha^{-1}) applications in both years. N applications comparing control plots affected the yield per plant, plant height, number of heads per plant, number of seeds per head, 1000 seed weight and biomass yield, had negative effect on the dry petal yield and oil ratio. Zn applications according to control plots whereas had positive effects on the seed yield per plant and number of heads per plant but had no significant effect on the dry petal yield and oil ratio. NxZn interactions affected the seed yield, number of heads per plant, number of seeds per head and biomass yield. 150 kg N ha^{-1} and 30 kg Zn ha^{-1} should be given to safflower under semi-arid conditions.
Keywords: *Carthamus, nutrients, dry petal, oil ratio, interaction*

Introduction and literature review

Sanliurfa is the hottest province of Southeastern Anatolia Region in Turkey. Harran Plain is located in the Sanliurfa city where continental climate, summers are very hot and dry and the winter are relatively temperate (Kose et al., 2018). Average annual rainfall is around 350-400 mm. Most of the rainfall falls in the winter season. Therefore, it is great important to cultivate drought-resistant plants in areas where irrigation is not possible. Safflower plant can be grown in this region under drought.

Safflower plant (*Carthamus tinctorius* L.) has quite various usage by stem, leaves, seeds and flowers. It is a very important industrial plant neglected and could not reach the place deserved. It is an historical species and it was cultivated in the Middle East 3000 years ago (Knowles, 1982). All parts of the plant are used in the treatment of various illnesses in India and Pakistan (Nimbkar, 2002). The flowers are used in the food, cosmetic, dye and pharmaceutical industries (Dajue and Mundel, 1996; Abd El-Mohsen and Mahmoud, 2013). Safflower was reported to be one of the alternative

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plants that can be considered in irrigated areas with its tolerance to salinity and weeds, and especially due to its high tolerance to cold and heat climatic conditions in arid regions (Emongor et al., 2015).

Safflower (*Carthamus tinctorius* L.) is one of the most important annual oil plants to be grown in winter season (Eslam, 2010; Gursoy et al., 2018). It is more resistant to drought and lower temperatures than other non-selective oil crops in terms of growth requirements safflower can also be grown in fallow areas especially in arid regions (Johnson et al., 1993). Due to these properties, safflower can be an alternative crop in crop rotation vs. wheat, barley, lentil and tobacco. It can help to alleviate the shortage of vegetable oil demand of Turkey (Eryigit et al., 2015; Kose, 2017). Safflower has yellow, red, orange and cream-colored flowers with thorny and thorn less forms, and it has been used for he production of edible oil and biofuels having 30-45% fat on average in its seeds (Demir and Kara, 2018).

Safflower seeds contain 13-46% oil, about 90% of this oil consisted of unsaturated fatty acids (oleic and linoleic acid) (Johnson et al., 1993; Belgin et al., 2007). Safflower oil containing an average of 75% linoleic acid (Weiss, 2000), and there are also its antioxidant effects and tocopherols with high vitamin E values. Therefore, safflower oil is used in diets applied by cardiovascular patients and has a great importance because of its anti-cholesterol effects (Pongracz et al., 1995).

Safflower petals are very important as a source of medicinal preparations, natural food colour and dyes for colouring fabrics. In addition to the colouring properties, safflower petals are used for curing several chronic diseases such as hypertension, coronary heart ailments, rheumatism and male and female fertility problems (Rajvanshi, 2005).

Since the safflower oil is suitable for biodiesel production, intensive researches on biodiesel production from safflower oil are carried out (Ogut and Oguz, 2006; Nosheen et al., 2011). The cartharmia substance obtained from the safflower is great important as a natural dye raw material (Nagaraj et al., 2001; Emongor, 2010). Especially the petals are used as food dyes and spices have potential to increase income from the unit area in the arid regions (Esendal, 2001).

In addition, some plant nutrients were found to be effective together with irrigation in direct to yield and yield components. Two of these important nutrients are nitrogen and zinc.

Nitrogen fertilizers are one of the important inputs in dry rainfed agricultural systems. In order to obtain optimum yield and quality product in these regions, sufficient amount of nitrogen in suitable time and form should be given to the plant. Excessive or insufficient N fertilizer applications result in some economic losses, excessive nitrogen application causes environmental problems over time (Grant, 2006). It was reported by many researches that the nitrogen fertilizer affected on the safflower growth, yield and quality properties significantly (Ahmed et al., 1985; El-Nakhlawy, 1991; Ibrahim, 1994). N fertilization increased seed yield (Strasil and Vorlicek, 2002); 300, 600 and 900 kg ha^{-1} N applications according to the control plots increased the biomass of safflower by 13.4%, 15.3% and 22.9% respectively (Haghighati, 2010). Nitrogen was effective on the vegetative and reproductive stages of safflower (Bitarafan et al., 2011); nitrogen applications increased seed yield 44.6-60.5% on average compared to the control plots (Singh and Singh, 2013); seed yield, 1000 seed weight, number of heads per plant and plant height were affected positively (Eryigit et al., 2015), and plant height and seed yield were increased (Revant Nathan et al., 2018) by

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the nitrogen fertilization. The effect of nitrogen may vary according to the amount, time and form of the application.

Zinc applications exhibited positive effect on the oil yield and seed quality, and besides, do the plant more resistant to drought conditions were reported by many researchers (Mengel, 2001; Khoshgoftarmanesh, 2010; Taha et al., 2013). Zinc has an important effect on the oil yield and quality, seed yield and biomass production (Lewis and McFarlane, 1986); Zinc sulphate application under water stress conditions increased seed yield, biomass and biological yield than control plots (Lakzayi, 2015); zinc application comparing central increased seed yield and number of heads per plant (Gulmezoglu and Aytac, 2016).

In this study, it is important to determine the effect of N and Zinc separately and in combination on the safflower crop under semi-arid climate conditions in the Harran Plain conditions. There have not been done such a study before under Harran plain conditions, because of that this study is important. As it is known, the genotypic structure of each plant is affected more or less from the environmental factors. The dose of the plant nutrient that is applied in a region has a good result, may not work well under any other environmental conditions. Therefore, it is great important to conduct these studies and determine the most appropriate doses in every ecological condition.

This study was carried out to asses the appropriate doses of the nitrogen and zinc on to seed yield and seed quality as well as disseminate the cultivation of safflower under semi-arid climatic conditions.

Materials and methods

Remzibey-05 safflower cultivar with yellow flowers, spiny leaves and head was used as plant material. The experimental area has a flat topography. It is well-drained deep, stone-free, with high clay content (54-56%). Soil pH is between 7.3-7.2, the salt content is 0.088-0.092%, and low in organic material 1.25-1.19%. In addition, the amount of pure N 25-19 kg ha^{-1}, P_2O_5 amount of pure 27-30 kg ha^{-1} and K_2O 1086-1129 kg ha^{-1} was determined (*Table 1*).

Table 1. *Some soil properties of experimental area (Anonymous, 2012)*

Years	Total Salt (%)	Lime (%)	Sand (%)	Clay (%)	Silt (%)	Organic Matter (%)	pH	N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})
2011	0.088	5.1	25.12	54	20.20	1.25	7.3	25	27	1086
2012	0.092	5.4	26.03	56	20.32	1.19	7.2	19	30	1129

Field trials were setup employing according to the randomized complete block design split plots with three replications in the experimental area Department of Field Crops of Agricultural Faculty, Harran University Eyyubiye Campus (37°06'59.1" N 38°49'15.8" E) (altitude = 510 m from sea level) (*Fig. 1*).

Each plot consisted of 5 m long with 5 rows. Inter-row and intra-row spaces were 35 and 15 cm respectively (*Fig. 2*). After experimental area had been ploughed, herbicide (*Trifluarin* active ingredient) was applied by a sprayer before planting. Then, Disk-harrowing was practiced for trial seedbed preparation tillage.

The sowing was practiced on 5th November, 2011 and 3th November, 2012 by the experimental drill. 2 m alley was left between each plot. After the emergence, thinning

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was practised in the stages of 3 or 4 leaves. The cultural practices (hoeing, weeding and pest management) were performed when needed in accordance with the conventional methods.

Figure 1. *The map of the experimental area*

Figure 2. *Experimental area*

In both growing seasons, total precipitation occurred close to each other. The average temperature (13.76 °C) for the 2011-2012 growing season was very close to the average for long years (13.68 °C), but the average temperature for the 2012-2013 growing period (15.31 °C) was higher than the average of the first year and long years of the experiment (*Table 2*). The higher average temperature in the second year of the

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experiment and the higher monthly precipitation, especially in May, may have caused the better development of the plant.

Table 2. *Some of meteorological characteristics for long term (1929-2013) and 20011-2013 period in Sanliurfa, Turkey (Anonymous, 2013)*

	2011-2012			2012-2013			1929-2013
Months	**Average monthly temp. (°C)**	**Precipitation (kg m^{-2})**	**Average relative humidity (%)**	**Average monthly temp. (°C)**	**Precipitation (kg m^{-2})**	**Average relative humidity (%)**	**Average of long-term (°C)**
November	9.4	62.1	53.7	14.9	68.4	65.6	12.9
December	7.4	47.1	57.4	8.3	142.8	73.0	7.5
January	5.5	170.9	81.0	6.8	86.8	69.5	5.4
February	5.8	95.8	57.0	9.3	107.2	73.6	6.8
March	9.7	35.8	47.3	12.9	12.1	-	10.7
April	19.3	23.3	42.4	18.4	18.0	44.9	16.0
May	22.4	42.3	40.8	22.9	56.2	43.4	22.1
June	30.6	5.8	21.2	29.0	-	24.0	28.0
Average	13.76		50.1	15.31		49.25	13.68
Total		483.1			491.5		

In the study, N applications (N_0 = no fertilization, N_5 = 50 kg ha^{-1}, N_{10} = 100 kg ha^{-1} and N_{15} = 150 kg ha^{-1}) were placed in the main plots, Zn applications were assigned in the sub-plots (Zn_0 = no fertilization, Zn_1 = 10 kg ha^{-1}, Zn_2 = 20 kg ha^{-1} and Zn_3 = 30 kg ha^{-1}). Half of the nitrogen was applied in the form of Ammonium Sulphate (21%) with the sowing, the remaining half in the form of ammonium nitrate (33%) at the branching stage. All the zinc in the form of ZnSO4 $7H_2O$ (23%) was applied with the sowing in 5-6 cm next to the plant rows and 5-6 cm deep by hand. Superphosphate (pure phosphorus 80 kg ha^{-1}) was applied as basal fertilizer at sowing.

Harvest was performed by hand for the seed and biomass yield from the remaining area (4 m × 1.05 m = 4.2 m^2) by thrown away the side effects of 0.5 m at the beginning and end of 3 rows in the middle of each plots on 5th June, 2013 and 6th June, 2013. Seed yield per plant (g plant^{-1}), plant height (cm), number of heads per plant (pieces plant^{-1}), number of seeds per head (pieces head^{-1}), 1000 seed weight (g) and dry petal yield (g plant^{-1}) were determined on randomly selected 10 plants (Esendal et al., 1992). A sufficient amount of seed (10 g) was grinded for each application and dried in the oven at 70 °C for 72 hours. 5 g of each sample boiled for 6 hours by using hexane in soxhlet extraction device and so on oil ratios (%) were scored.

The data was subjected to analysis of variance utilizing the JMP 11 (SAS Institute 2013, USA) statistical program in the randomized complete blocks design split plots and averages were grouped by the Tukey HSD test ($p \leq 0.05$).

Results and discussion

In the analysis of variance (ANOVA) according to the combined years of the properties examined in the trial, statistical differences were found between years. Due to that the results of each year were analyzed separately.

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Seed yield (kg ha^{-1})

N_{15} application gave the highest seed yield (1171 and 1651 kg ha^{-1}) in both years of the experiment. Strasil and Vorlicek (2002), Singh and Singh (2013), Eryigit et al. (2015) and Revant Nathan et al. (2018) reported that the nitrogen fertilization increased yield is consistent with the research results. The highest seed yield in Zn application was obtained from the Zn_3 application (1233 and 1675 kg ha^{-1}) in both years. Taha et al. (2013), Lakzayi (2015) and Gulmezoglu and Aytac (2016) observed that the zinc applications increased seed yield comparing to the control. In the first year of the experiment N_{15} x Zn_3 interaction (1463 kg ha^{-1}), in the second year N_0 x Zn_3 (1887 kg ha^{-1}), N_{10} x Zn_2 (1865 kg ha^{-1}) and N_{15} x Zn_3 (1900 kg ha^{-1}) interactions gave the highest seed yield (*Table 3*). N_{15} x Zn_3 interaction gave the highest seed yield (1463 and 1900 kg ha^{-1}) in both years shows that the application in these doses increase the seed yield. High yield in second year comparing that of first year can be attributed to fluctuating climate and environmental factors.

Seed yield per plant (g plant^{-1})

Statistically significant differences were found between N and Zn applications in both years. N_{15} (8.44 and 11.98 g) and Zn_3 (8.68 and 11.25 g) applications gave the highest seed yield per plant in both years. In general, obtained the better yields in the second year than the first year can be attributed to environmental and climatic conditions. N_{15} x Zn_3 interaction gave the highest seed yield (10.83 and 13.57 g) in both years indicates that the application at these doses increases seed yield per plant (*Table 3*).

Seed yield per plant is a factor that directly affects seed yield per hectare. As a matter of fact, the highest values obtained from the N_{15} and Zn_3 applications for seed yield per hectare confirmed the research results. Eryigit et al. (2015) and Revant Nathan et al. (2018) reported that the nitrogen fertilization increased seed yield per plant, and Taha et al. (2013); Gulmezoglu and Aytac (2016) zinc fertilization as well.

Plant height (cm)

N_5 application (142.0 cm) in the first year, N_{15} application (141.6 cm) in the second year gave the highest plant height values (*Table 1*). Khalil et al. (2013) and Eryigit et al. (2015) report that the nitrogen fertilization increases plant height which was consistent with the research results. Similar results were also reported by Katar et al. (2012) and Bitarafan et al. (2011).

As the zinc applications had not any effects on the plant height in the first year, Zn_2 application gave the highest plant height (140.3 cm) in the second year. N_5 x Zn_2 interaction (144.8 cm) in the first year, N_0 x Zn_3 (143.3 cm) and N_5 x Zn_2 (143.0 cm) interactions in the second year gave the highest plant height scores (*Table 3*).

Plant height is significantly affected by environmental factors. The highest plant height scores from the different applications in both years can be due to the fact that the plants grow in all kinds of natural areas that are open to various impacts and they are very much under different environmental conditions during the growth and development periods (Arslan and Bayraktar, 2015). However, the highest plant height from the N_5 x Zn_2 (144.8 and 143.0 cm) interaction in both years showed that the application at these doses increases the plant height.

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Table 3. *Averages and groups of main (N), sub variables (Zn) and interactions (NxZn) for seed yield (kg ha^{-1}), seed yield per plant (g plant^{-1}) and plant height (cm)*

Treatments		**Seed yield (kg ha^{-1})**		**Seed yield per plant (g plant^{-1})**		**Plant height (cm)**	
N		**2011-12**	**2012-13**	**2011-12**	**2012-13**	**2011-12**	**2012-13**
N_0		1045 b*	1612 b*	8.07 a*	9.85 c*	139.7 b*	140.1 b*
N_5		985 c	1565 c	6.55 b	11.10 ab	142.0 a	139.1 b
N_{10}		1147 a	1594 b	8.43 a	10.14 bc	139.6 b	135.3 c
N_{15}		1171 a	1651 a	8.44 a	11.98 a	138.2 b	141.6 a
Zn		**2011-12**	**2012-13**	**2011-12**	**2012-13**	**2011-12**	**2012-13**
Zn_0		1110 b*	1473 c*	8.03 b*	10.65 b*	140.4 ns	138.4 bc*
Zn_1		1020 c	1674 a	7.83 b	11.35 a	140.2	137.6 c
Zn_2		985 c	1602 b	6.94 c	9.81 c	139.4	140.3 a
Zn_3		1233 a	1675 a	8.68 a	11.25 a	139.5	139.7 ab
Interactions		**2011-12**	**2012-13**	**2011-12**	**2012-13**	**2011-12**	**2012-13**
N_o	Zn_0	1207 bcd*	1461 gh*	8.54 b*	10.57cd*	140.6 abc*	138.2 b-f*
	Zn_1	1158 b-e	1698 c	7.69 bd	11.31 bc	138.5 bc	136.7 c-g
	Zn_2	984 gh	1560 de	7.57 bcd	10.30 cd	139.4bc	142.3 ab
	Zn_3	1243 b	1887 a	8.49 bce	12.65 ab	140.2 abc	143.3 a
N_5	Zn_0	1015 fg	1414 h	6.58 cde	10.35 cd	139.2 bc	139.9 a-e
	Zn_1	894 h	1599 d	6.56 de	9.25 d	141.6 ab	136.2 efg
	Zn_2	921 gh	1564 de	6.14 e	9.90 cd	144.8 a	143.0 a
	Zn_3	1111 de	1683 c	6.92 cde	13.67 a	142.5 ab	137.4 c-g
N_{10}	Zn_0	1209 bc	1494 fg	8.79 b	10.52 cd	142.6 ab	133.3 g
	Zn_1	923 gh	1790 b	8.99 b	10.31 cd	142.6 ab	136.6 d-g
	Zn_2	932 gh	1865 a	7.94 bcd	9.56 d	135.5 c	135.3 fg
	Zn_3	1115 cde	1228 ı	8.00 bcd	10.14 cd	137.6 bc	135.8 efg
N_{15}	Zn_0	1012 fg	1523 ef	8.72 b	10.44 cd	139.1 bc	142.3 ab
	Zn_1	1106 ef	1607 d	8.08 bc	10.22 cd	138.1 bc	141.0 abc
	Zn_2	1105 ef	1419 h	6.13 e	9.48 d	137.9 bc	140.8 a-d
	Zn_3	1463 a	1900 a	10.83 a	13.57 a	137.6 bc	142.5 ab
CV %		13.74	11.61	16.22	10.12	10.96	12.40
				F value			
	N	85.97 **	42.61 **	37.40 **	51.03 **	9.38 **	44.19 **
	Zn	141.55 **	295.95 **	24.63 **	27.01 **	0.97 ns	8.90 **
	NxZn	34.05 **	379.11 **	9.28 **	15.70 **	5.73 **	7.88 **

*Means followed by different letters within columns are significantly different ($p \leq 0.05$)
*$p \leq 0.05$, **$p \leq 0.01$, ns: non-significant

Number of heads per plant (pieces plant^{-1})

N_{10} application gave the highest number of heads per plant (17.7 pcs plant^{-1}) in the first year, N_{15} application gave the highest number of heads per plant (21.2 pcs plant^{-1}) in the second year. Bitarafan et al. (2011) and Eryigit et al. (2015) reported that nitrogen fertilization increases the number of heads per plant. In the first year of the experiment Zn_3 (18.7 pcs plant^{-1}), in the second year Zn_1 and Zn_3 applications (20.3 pcs plant^{-1})

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gave the highest number of heads per plant. Gulmezoglu and Aytac (2016) declared that Zinc application increased the number of heads per plant compared to the control plots in a research which was consistent with the research results. $N_{10}xZn_1$ (19.7 pcs plant^{-1}) and $N_{10}xZn_3$ (19.6 pcs plant^{-1}) interactions in the first year of the experiment, N_5xZn_3 (22.8 pcs plant^{-1}) in the second year gave the highest number of heads per plant (*Table 4*).

Table 4. *Averages and groups of main (N), sub variables (Zn) and interactions (NxZn) for number of heads per plant (pieces plant^{-1}), number of seeds per head (pieces head^{-1}) and 1000 seed weight (g)*

Treatments		Number of heads per plant (pieces plant^{-1})		Number of seeds per head (pieces head^{-1})		1000 seed weight (g)	
N		**2011-12**	**2012-13**	**2011-12**	**2012-13**	**2011-12**	**2012-13**
N_0		17.5 ab*	19.2 b*	14.3 ab*	11.7 b*	29.11 ab*	28.77 b*
N_5		16.9 b	19.2 b	12.5 b	11.6 b	27.86 b	29.45 ab
N_{10}		17.7 a	18.7 b	14.5 a	12.6 a	29.76 ab	29.85 a
N_{15}		17.2 b	21.2 a	15.5 a	12.9 a	30.01 a	29.88 a
Zn		**2011-12**	**2012-13**	**2011-12**	**2012-13**	**2011-12**	**2012-13**
Zn_0		17.3 b*	19.6 b*	14.8 ab*	12.4^{ns}	29.68^{ns}	29.94 a*
Zn_1		17.2 b	20.3 a	13.2 b	12.2	29.80	29.25 ab
Zn_2		16.1 c	18.2 c	13.2 b	12.3	28.58	28.62 b
Zn_3		18.7 a	20.3 a	15.6 a	11.9	28.69	30.15 a
Interaction		**2011-12**	**2012-13**	**2011-12**	**2012-13**	**2011-12**	**2012-13**
N_o	Zn_0	17.2 cde*	22.1 ab*	15.5 abc*	12.0 d-g*	30.73^{ns}	30.97 ab*
	Zn_1	18.8 ab	20.2 b-e	13.2 bc	12.1 c-f	29.33	28.98 ab
	Zn_2	16.2 efg	19.6 efg	13.1 bc	11.1 efg	28.07	28.94 ab
	Zn_3	17.7 bcd	22.1 abc	15.9 abc	11.1 efg	28.32	29.88 ab
N_5	Zn_0	18.5 abc	17.9 gh	11.3 c	11.7 d-g	27.97	29.05 ab
	Zn_1	15.5 fg	21.7 a-d	13.0 bc	10.6 fg	27.98	28.90 ab
	Zn_2	16.4 d-g	15.4 ı	12.9 bc	13.8 abc	27.70	28.88 ab
	Zn_3	17.3 cde	22.8 a	12.9 bc	10.4 g	27.81	31.72 a
N_{10}	Zn_0	19.0 ab	18.0 fgh	14.1 abc	12.7 b-e	29.37	29.66 ab
	Zn_1	19.7 a	19.3 e-h	14.2 abc	14.0 ab	31.20	30.59 ab
	Zn_2	15.3 g	20.0 def	14.5 abc	12.5 b-e	29.12	28.53 b
	Zn_3	19.6 a	17.6 h	15.4 abc	11.1 efg	29.33	30.64 ab
N_{15}	Zn_0	16.8 def	20.3 b-e	18.1 ab	13.2 a-d	30.67	29.33 ab
	Zn_1	15.4 g	20.1 cde	12.4 c	12.0 d-g	30.67	28.52 b
	Zn_2	16.3 d-g	17.8 gh	12.3 c	11.7 d-g	29.42	28.10 b
	Zn_3	17.3 cde	18.7 e-h	19.0 a	14.7 a	29.30	29.12 ab
CV %		8.56	10.38	17.26	10.60	5.93	4.20
F value							
	N	5.98 *	33.28 **	5.21 *	16.84 **	4.40 *	3.53 *
	Zn	62.12 **	28.05 **	5.54 *	1.81 ns	2.09 ns	6.37 *
	NxZn	24.18 **	26.38 **	3.32 *	19.65 **	0.46 ns	2.24 ns

*Means followed by different letters within columns are significantly different (p ≤ 0.05)
*p ≤ 0.05, **p ≤ 0.01, ns: non-significant

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The most important selection criteria for seed yield was the number of heads per plant. The number of heads is a property that is affected by the plant genetic structure, sowing density, fertilization and other environmental factors. Implemented that the difference between the results and applications of other researchers in terms of number of heads per plant could be caused by the variations in climate and soil structure of the location where the research was carried out and cultivar, and the differences between different cultural techniques, sowing and harvest dates.

Number of seeds per head (pieces head^{-1})

N_{10} and N_{15} applications gave the highest number of seeds per head in both years. The highest number of seeds per head by the nitrogen fertilization increased seed yield per plant, and therefore contributed positively to the seed yield per hectare in the trial. Strasil and Vorlicek (2002); Singh and Singh (2013) and Eryigit et al. (2015) reported that the nitrogen fertilization increased yield was consistent with our research results. As the Zn_3 application gave the highest number of seeds per head (15.6 pcs head^{-1}) in the first year, there were no statistically significant differences between the applications in the second year. $N_{15}xZn_3$ interaction gave the highest number of seeds per head (19.0 and 14.7 pcs head^{-1}) in two years (*Table 4*).

When examined the interactions, N_{15} x Zn_3 interactions was promising. Bitarafan et al. (2011) indicated that nitrogen was effective in vegetative and reproductive development; Soleymani and Shahrajabian (2011), nitrogen increased the number of seeds per head, and Lewis and McFarlane (1986), Zn had an important role on the oil yield and quality, seed yield and biomass production are compatible with the research results. The number of seeds per head as well as the number of heads per plant were the important criterion for yield. The number of seeds per head was directly related to the head size and that can be affected fairly by genetic and environmental factors. Although an average of 100 flowers were formed in each safflower head, 20% of these flowers formed seed (Baydar, 2000).

1000 seed weight (g)

N_{15} application (30.01 g) in the first year of the experiment, N_{10} and N_{15} applications (29.85 and 29.88 g) in the second year gave the highest 1000 seed weight. Nitrogen fertilization gave the more 1000 seed weight values than control plots in both years. Bitarafan et al. (2011); Khalil et al. (2013) and Eryigit et al. (2015) reported that nitrogen doses increased 1000 seed weight comparing the control. Although Zn applications were insignificant in the first year, Zn_0 and Zn_3 applications (29.94 and 30.15 g) gave the maximum 1000 seed weight values in the second year. At the same time, N x Zn interactions were in non-significant in the first year, N_5 x Zn_3 interaction gave the highest 1000 seed weight (31.72 g) in the second year (*Table 4*). These differences between years might be due to different soil and climate factors.

Dry petal yield (g plant^{-1})

The highest petal yields (1.12 and 1.19 g) were obtained from control N_0 subject according to the N application, from the Zn_0 (1.17 and 1.27 g) subject according to the Zn application in both years. N_0 x Zn_1 and N_{10} x Zn_0 interactions gave the highest petal yield in the first (1.47 and 1.45 g) and second year (1.70 and 1.65 g) (*Table 5*). Control

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plots created more petal yields. This indicated that N and Zn applications had negative effects on the petal yields.

Table 5. *Averages and groups of main (N), sub variables (Zn) and interactions (NxZn) for dry petal yield (g plant^{-1}), oil ratio (%) and biomass yield (tons ha^{-1})*

Treatments		Dry petal yield (g plant^{-1})		Oil ratio (%)		Biomass yield (tons ha^{-1})	
N		**2011-12**	**2012-13**	**2011-12**	**2012-13**	**2011-12**	**2012-13**
N_0		1.12 a*	1.19 a*	30.0 a*	31.3 a*	5.808 c*	9.238 ab*
N_5		1.02 bc	1.04 c	30.1 a	31.4 a	6.617 a	8.612 b
N_{10}		0.98 c	1.00 d	29.5 b	29.8 b	6.058 b	9.467 a
N_{15}		1.04 b	1.12 b	30.1 a	30.6 ab	6.217 b	9.648 a
Zn		**2011-12**	**2012-13**	**2011-12**	**2012-13**	**2011-12**	**2012-13**
Zn_0		1.17 a*	1.27 a*	29.9^{ns}	30.4^{ns}	6.571 a*	9.111 b*
Zn_1		1.08 b	1.13 b	30.0	30.9	5.742 c	9.600 a
Zn_2		1.05 c	1.11 b	29.1	30.7	6.137 b	9.215 b
Zn_3		0.86 d	0.84 c	29.7	31.0	6.250 b	9.040 b
Interaction		**2011-12**	**2012-13**	**2011-12**	**2012-13**	**2011-12**	**2012-13**
N_o	Zn_0	1.13 cd*	1.27 c*	29.9^{ns}	30.3 c-f*	6.550 abc*	9.420 bcd*
	Zn_1	1.47 a	1.70 a	30.0	30.5 b-f	4.700 g	9.000 cd
	Zn_2	0.77 fg	0.71 fg	30.0	33.1 a	5.617 ef	8.640 de
	Zn_3	1.09 d	1.08 d	30.2	31.2 b-e	6.367 a-d	9.893 bc
N_5	Zn_0	1.20 c	1.24 c	30.3	30.7 b-f	6.700 ab	7.667 f
	Zn_1	0.84 ef	0.84 e	29.7	31.0 b-f	6.533 abc	9.827 bc
	Zn_2	1.17 c	1.20 c	30.3	31.8 a-d	6.833 a	7.413 f
	Zn_3	0.84 ef	0.89 e	30.0	32.1 abc	6.400 a-d	9.543 bcd
N_{10}	Zn_0	1.45 a	1.65 a	29.2	30.0 efg	6.933 a	9.260 bcd
	Zn_1	0.66 h	0.63g	30.3	30.0 efg	5.967 c-f	9.800 bc
	Zn_2	1.09 d	1.05 d	29.2	28.6 g	6.000 c-f	10.900 a
	Zn_3	0.75 g	0.67 fg	29.3	30.6 b-f	5.333 fg	7.907 ef
N_{15}	Zn_0	0.91 e	0.91 e	30.1	30.6 b-f	6.100 b-e	10.097 ab
	Zn_1	1.35 b	1.37 b	30.1	32.2 ab	5.767 def	9.773 bc
	Zn_2	1.17 cd	1.45 b	30.4	29.4 fg	6.100 b-e	9.907 bc
	Zn_3	0.75 g	0.74 f	29.4	30.2 d-g	6.900 a	8.817 de
CV %		14.46	11.82	5.93	4.20	10.10	10.57
F Value							
	N	54.90 **	95.21 **	4.80 *	20.35 **	24.03 **	26.97 **
	Zn	312.99 **	425.03 **	1.25 ns	2.91 ns	28.82 **	8.24 **
	NxZn	364.42 **	479.56 **	3.15 *	12.06 **	17.78 **	38.28 **

*Means followed by different letters within columns are significantly different ($p \leq 0.05$)
*$p \leq 0.05$, **$p \leq 0.01$, ns: non-significant

Oil ratio (%)

N_0 (30.0%), N_5 (30.1%) and N_{15} (30.1%) subjects gave the highest oil ratio in the first year, N_0 and N_5 (31.3 and 31.4%) treatments in the second year and these formed in

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the same group. The formation of similar groups in two years reveals that the application of N did not have a positive effect on oil ratios. Kolsarici et al. (2005) and Elfadl et al. (2009) reported the similar results in their studies. Zn applications had not statistically significant in both years. Although N x Zn interaction was insignificant in the first year, N_0 x Zn_2 interaction gave the highest oil ratio (33.1%) in the second year (*Table 5*). These differences between the experimental years might be due to the various effects of environmental factors.

Biomass yield (tons ha^{-1})

N_5 application gave the highest biomass yield (6.617 tons ha^{-1}) in the first year, N_{10} and N_{15} applications (9.467 and 9.648 tons ha^{-1}) in the second year. When scores of characteristics for two years were evaluated, N applications generated the more biomass yield than the control plots. Several researchers reported that N applications increased biomass yield comparing to the control (Haghighati, 2010; Singh and Singh, 2013 and Revant Nathan et al., 2018). The highest biomass yield (6.571 tons ha^{-1}) in Zn applications was obtained from the Zn_0 application in the first year, from the Zn_1 application (9.600 tons ha^{-1}) in the second year. N_0 x Zn_2 (6.933 tons ha^{-1}) and N_{15} x Zn_3 (6.900 tons ha^{-1}) interactions in the first year, N_{10} x Zn_2 (10.900 tons ha^{-1}) interaction in the second year gave the highest biomass values (*Table 5*).

Biomass yields are affected by environmental factors. Especially, N applications with high precipitation enhance the vegetative development of the plant. Nitrogen with water, is the most vital nutrient. Therefore, it appears to be a nutrient that controls plant growth (Fageria, 2009). Zinc affects the nitrogen metabolism, starch formation and seed maturation in plants. Zinc a plant nutrient element necessary for the production of growth hormones (auxin hormone), and especially for the prolongation of the internode (Gardiner and Miller, 2008; McCauley et al., 2009). For these reasons, N and Zn applications are important in safflower production. The differences between N x Zn interactions in the research may have been caused by the diversities of climate and soil factors.

Conclusions

It was concluded that; the highest seed yield and seed yield per plant were obtained from the both N_{15} x Zn_3 interaction and N_{15} and Zn_3 applications. Although N applications had the positive effects comparing to the control plots on the seed yield per plant, plant height, number of heads per plant, number of seeds per head, 1000 seed weight and biomass yield and had no any positive effects on the dry petal yield and oil ratio. Zn applications had showed positive effects comparing to the control plots on the seed yield per plant and number of heads per plant and had negative effects on the oil ratio and dry petal yield. As a result of the research; the highest seed yield and seed yield per plant from the N_{15} and Zn_3 applications were lower than those of the N_{15} x Zn_3 interaction, and the doses of 150 kg N ha^{-1} and 30 kg Zn ha^{-1} should be given together in N and Zn applications under semi-arid conditions. However, as each region has its own climate and soil conditions, it is useful to perform these studies where safflower cultivation is done.

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