The Effects of Different Row Distances and Nitrogen Fertilizer Rates on Yield and Yield Components of Safflower (*Carthamus tinctorious*) Under Micro-Climate Conditions of Iğdır Plain -Turkey

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Abstract—The growth and productivity of Safflower (*Carthamus tinctorius*) are influenced by many factors such as genotype, environment and agronomic practices. In order to determine the yield and yield components of safflower under effects of different row distance (RD1=20, RD2=30 and RD3=40 cm) and various nitrogen rates (N1= 0, N2= 100, N3= 150, and N4= 200 kg N ha^{-1}), a study was lied out in Agricultural Research Fields of Iğdır University, Iğdır, Turkey during 2011–2012 on the basis of randomized complete block design with three replications.

The study indicated that the effect of RD was significant for all traits, except of 1000 seed weight and seed protein content, and the effect of N, except of seed oil content was significant for all traits. RD x N had significant effect on the plant height. Increasing N rate with the wider row distance influenced plant height, the number of branch per plant, the number of head per plant, 1000 seed weight, seed yield and seed protein content, positively. Seed yield increased with N fertilization up to 150 kg ha^{-1} but decreased again at a higher N rate. Tight of row distances decreased all properties significantly, except of plant height, 1000 seed weight and seed protein content. The response of seed oil content to RD was negligible.
However, there was high seed yield in 2011 as compared to 2012. Among row distancess, RD2 and RD3 gave more yield as compared to RD1, while in case of N rates, N3 (150 kg ha^{-1}) provided higher yield than other N rates (0, 100 and 200 kg ha^{-1}) in both years of study especially during 2011.

Keywords— Safflower, row distance, nitrogen rates, yield

I. Introduction

SAFFLOWER (*Carthamus tinctorius* L.) is an annual, a strongly tap-rooted, broadleaf oilseed crop with 35-40% oil from the family Asteraceae (Compositae) [1], [2] that has long been cultivated for different purposes, such as oil, fabric dyes, food coloring, medicinal and industrial needs [3], [4] and [5]. It adapted mainly to dry land, irrigated cropping systems and resistant to saline conditions [6] and [7], [8]. However, the growth and productivity of Safflower are influenced by many factors such as genotype, environment and agronomic practices. Among these factors, the drought stress is a common problem in arid and semi-arid regions such as East, South East and Central Anatolia where rainfall is insufficient. Due to its strong and outspread root characteristic, safflower uptakes moisture and nutrients from relatively high depths of soil [9] and also, as an alternative crop it has gained importance in these regions, because of its drought and cold resistant.

In addition to these factors such as nitrogen fertilization is one of the most important factors determining yield due to its multidimensional effects on the growth and development of safflower. Safflower has a higher need of nitrogen than other nutritional elements for its optimum vegetative and generative development [10]. Therefore it is necessary to apply sufficient amount of nitrogen to obtain optimum yield and high-quality product.

The other important factor for optimizing safflower productivity is the appropriate plant density (row distance and intra-row sapcing). Plant density is an important factor in determining safflower yield under the microenvironment conditions. Therefore, optimization of this factor can lead to a higher yield in the crop by favorably affecting the absorption of nutrients and exposure of the plant to the light [3].

The objective of this study was to determine the optimum nitrogenous fertilizer rates and row distances for safflower cultivar Remzibey which can grow under the Iğdır Plain ecological conditions in Iğdır-Turkey.

II. Materials And Methods

The experiment was carried out at the trial field of Agricultural Research and Training Center (lat. 39° 55'-N, long. 44° 5'-E and the alt. 851 m above sea level) of Iğdır University, Turkey during 2011 and 2012 growing seasons.

The soil samples where the experiment took place were taken before field preparation to identify its physical and chemical properties which results are presented in Table 1.

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TABLE I
SOIL CHARACTERISTICS OF THE EXPERIMENTAL FIELD IN IĞDIR-TURKEY, WHERE THE STUDY WAS CONDUCTED

Soil Texture (Type)	**EC** (mmhos/cm)	**pH**	**Lime** ($CaCO_3$) (%)	**Total N** (%)	**Organic Matter** (%)	**Available plant nutrients (kg ha^{-1})** P_2O_5	K_2O
Clay - Loam	1.85	7.99	11.81	0.98	2.1	34	271

The meteorologic statistics during the study periods of both years are presented in Table II. The monthly mean temperatures of the growing period (April-September) was nearly equal to the long-term monthly mean temperatures in 2011, while the mean average of 2012 consistently higher than 2011. The higher temperatures were screened during the reproductive stages. As seen in Table II, the total precipitation (250.1mm) of 2011 was higher than the total precipitation (153.2mm) of 2012, while the total precipitation of 2012 approximately similar to the long-term. Monthly precipitation differed in both 2011 and 2012 at the growth stages. During the vegetative stages (April-July), the crops received higher precipitation in 2011 than in 2012. However, the plants received higher precipitation during reproductive stages (August-September) in 2011 compared to 2012. The average of relative humidity (49.0 %) of 2011 was nearly similar to the long-term (48.4), while 2012 humidity average (64.2 %) was higher than both 2011 and the long-term.

TABLE II
METEOROLOGICAL STATISTICS FOR THE STUDY PERIODS IN 2011 AND 2012 IN IĞDIR-TURKEY

Months	**Mean monthly temp. (°C)**			**Precipitation (mm)**			**Mean relative humidity (%)**		
	2011	**2012**	**LT**	**2011**	**2012**	**LT**	**2011**	**2012**	**LT**
April	13.5	17.8	13.3	73.9	16.2	37.6	57.7	52.0	49.4
May	17.5	21.0	17.6	76.9	57.4	48.8	59.8	63.0	51.2
June	23.5	26.5	22.2	40.4	26.7	32.2	47.0	31.0	47.3
July	28.0	27.2	26.0	24.0	23.0	14.3	40.5	89.0	44.7
August	25.9	29.8	25.2	24.3	0.6	9.6	43.2	70.0	46.7
September	21.4	22.7	20.1	10.6	29.3	10.0	45.8	80.0	51.0
Total/Mean	**21.6**	**24.2**	**20.7**	**250.1**	**153.2**	**152.5**	**49.0**	**64.2**	**48.4**

* **LT:** Long Term

The study was laid out on randomized complete block design, arrangement with four replications where 12 treatments including twelve main plot with row distances (RD1=20cm, RD2=30cm and RD3=40cm) and four nitrogen rates (Ammonium Sulphate (21% N); N1:0 kg N ha^{-1}, N2:100 kg N ha^{-1}, N3:150 kg N ha^{-1} and N4:200 kg N ha^{-1}) in sub plot, respectively. All plots were 5m long. The distance between main plots is 2 m and sub plot is 1 m. Each plot consisted of five rows where the commercial cultivar Remzibey-05 was used as material. The half of all nitrogen rates were applied during seedbed preparation, and triple super-phosphate as fertilizer (46% P2O5) was mixed with the soil (60kg ha^{-1}) before sowing.

Sowing was performed on May 4, 2011 and April 20, 2012. After emergence, thinning was performed to obtain row distances (20, 30 and 40cm) and weeding was applied before stem elongation manually.

Yield, yield components and other agronomic traits' datas (plant height, main branch per plant, number of head per plant, 1000 seed weight, seed yield, seed oil content and seed protein content) were recorded on 10 plants randomly selected from three middle rows in each subplot where the harvesting areas determined after deletion of the plot sides and 30cm from the top and bottom of three middle rows.

After data collection, analysis of data variances for each attribute and analysis of the randomized complete block designs in two years were computed using the IBM SPSS computer program (v.20.0). F test in analysis of the experiments was carried out using expected values of the mean squares which year and replication were assigned as random factors and row distances and nitrogen rates were considered as fixed factors. The Duncan's multiple range tests was used to test the significance of main effects at the 5 % level of probability. The MSTATC software package was used to test significant interaction effects between treatments. The Spearmen correlation equation between the traits mean as the dependent variables of safflower as the independent variable are calculated by IBM SPSS.

III. RESULTS AND DISCUSSION

Variance components and mean comparisons for yields, yield components, oil and protein contents are presented in Tables 3, 4 and 5, respectively.

A. Plant height

Analysis of variance showed (Table 3) that the simple effect of the years was statistically significant on plant height at % 1 probability level. The means comparison for this trait (Table 4) indicated that safflower in 2012 was faced a more favorable thermal and moisture regime than in 2011. The variations between plant heights within two years could be due to differences in the climatic factors. Because, low precipitation caused a reduction in plant height (Table 2) which was due to increase in terminal temperature during the growing season in 2012, which is also confirmed by [11]. Therefore the maximum plant height (73.68cm) achieved in 2011 (Table 4).

TABLE III
COMBINED VARIANCE ANALYSIS OF THE EFFECTS OF YEAR, ROW DISTANCES AND NITROGEN RATES ON QUANTITATIVE CHARACTERS OF SAFFLOWER

Sources of Variations	**df**	**Mean Squares**													
		Plant height (cm)		Main branch number per plant		Head number per plant		1000-seeds weight (g)		Seed yield (kg ha^{-1})		Seed oil content (%)		Seed protein content (%)	
Blocks	2	8.431	ns	0.420	ns	0.457	ns	0.443	ns	766.365	ns	0.366	ns	0.023	ns
Main Effects															
Y	1	1 935.664	**	1.296	ns	4.831	ns	2.405	**	1 256 001.600	**	4.181	**	2.773	**
RD	2	113.461	*	5.754	**	19.420	**	0.091	ns	62 459.931	**	0.739	*	0.111	ns
N	3	365.655	**	4.121	**	40.125	**	3.855	**	985 568.850	**	0.209	ns	3.672	**
Interactions															
Y x RD	2	19.871	ns	0.788	ns	2.891	ns	0.900	*	1 143.049	ns	0.379	ns	0.007	ns
Y x N	3	208.824	**	0.189	ns	0.779	ns	0.266	ns	213 292.160	**	0.005	ns	0.006	ns
RD x N	6	43.331	*	0.600	ns	2.124	ns	0.143	ns	3 251.614	ns	0.319	ns	0.102	ns
Y x RD x N	6	5.288	ns	0.174	ns	0.684	ns	0.280	ns	3 156.445	ns	0.227	ns	0.006	ns
Error (TE)	46	17.096		0.609		2.209		0.169		1 803.268		0.182			
CV%		6.036		13.309		13.788		0.979		2.173		1.410		2.113	

*P <0.05; ** P < 0.01; **B**: Block; **Y**: Year of sowing; **RD**: Row distance; **N**: Nitrogen; **TE:** Total error

As can be seen in Table 3, plant heights had statistically significant (5%) differences among the row distances. The plant heights obtained from row distances (RD1, RD2 and RD3) were 70.40, 68.96 and 66.13cm, respectively (Table 4). The closer row distances produced higher plants, due to the competition between plants for sunlight. The recent results confirm the findings of Kolsarici and Güney [12]

Statistical analysis of plant height showed significant (1%) differences among the nitrogen rates (Table 3). According to the nitrogen rate values in Table 4, the highest plant (72.13cm) was observed in plots with nitrogen rates of N3 and the lowest plant height (61.92cm) was measured in control plots. The results revealed that increases in nitrogen level usually increase plant height. Similar results were also reported by Khalil, Dagash [13], Bitarafan, Shirani-Rad [10] and Katar, Arslan [14].

As shown in Table 3, the effects of the interactions of Y x N (1%) and RD x N (5%) were statistically significant on plant height. As can be seen in Fig. 1, the interaction of Y1 x N1 showed greater plant height (80.32cm) and Y2 x N1 screened lower one (61.07cm) (Table 5). In Table 5, the maximum plant height (77.71cm) was obtained from RD1 x N3 interaction and the minimum plant height (60.12cm) observed from RD3 x N1 interaction (Fig. 1).

B. Main branch number per plant

Data of variance analysis on Table 3 showed that the simple effect of the row distances on main branch number per plant was statistically significant at 1% probability level. Number of main branch per plant significantly varied with row distances. According to the means comparison in Table 4, the maximum number of branches (6.36) was observed from RD2 where the minimum values (5.39, 5.84) obtained from RD1 and RD3, respectively. In a previous study, it was reported that wider plant distance increased the biomass of the plant by producing healthy plant parts by receiving maximum sun light for the process of photosynthesis [15]. The study results agree with the previous findings of Katole and Meena [16] and Oad, Samo [15] who reported that growth parameters of safflower crop are significantly influenced by plant density.

As seen in Table 4, nitrogen rates of N3 and N4 produced the highest main branch number (6.34, 6.21) where N1 (control) and N2 produced the lowest (5.42, 5.49) ones. The results of this trait had a good line with findings of Elfadı, Reinbrecht [17] and Mohamed, Jellings [18] who reported that an excess of nitrogen can increase more branches (main, secondary and tertiary branches).

C. Head number per plant

According to the results of variance analysis in Table 3, the simple effect of years was statistically significant on head number/plant at 1% probability level. As seen in Table 4, the highest head number per plant value (11.04) was obtained in 2011 than (10.52) in 2012. These differences may be occurred due to the negative effects of climatic stress during reproductive period in 2012, resulting in the minimum head number/plant.

Table 3 shows that the differences in row distance had significant (1%) effects on safflower heads number/plant. The highest head number/plant value (17.70) was obtained in RD3 plots, where the lowest head number/plant (9.9) was produced from RD1 treated plots (Table 4).

Data presented in the Table 4 shows that nitrogen rates had a significant (1%) effect on head number/plant in safflower crop. The highest value (12.14) was obtained in plots that treated with N3. The minimum value (9.39) was produced in control plots (Table 4). Nitrogen increases the primarily number of branches per plant through its effect on number of heads/plant and the increase is greater in secondary and tertiary heads. Similar results were also reported by other researchers [10, 12, 19].

D. 1000-seed weight

As the results of the analysis of variance (Table 3) showed, the sample effect of the years was significant (1%) on 1000-seed weight.

The1000-seed weight increased with increasing of row distances, but this variation statistically wasn't significant (1%) (Table 3). The mean values of 1000-seed weight were 41.94, 42.03 and 42.06 g, respectively (Table 4).

The data screened in Table 3 showed that nitrogen rates had highly significant (1%) effect on 1000-seed weight. The highest values (42.39 and 42.29 g) were obtained in plots that received N3 and N4, respectively, where the minimum value (41.37 g) was observed in N1 (Table 4).

TABLE IV
COMPARISON TEST OF DUNCAN'S MEAN FOR THE EFFECTS OF YEAR, ROW DISTANCES AND NITROGEN RATES ON QUANTITATIVE CHARACTERS OF SAFFLOWER

Factors		Plant height (cm)	Main branches per plant	Head number per plant	1000-seeds weight (g)	Seed yield (kg ha^{-1})	Seed oil content (%)	Seed Protein content (%)
Y	**2011**	73.68 **A**	6.00	10.52 **A**	42.19 **A**	2069.95 **A**	30.54 **A**	13.32 **B**
	2012	63.31 **B**	5.73	11.04 **B**	41.83 **B**	1805.81 **B**	30.06 **B**	13.71 **A**
LSD 0.05		**1.961**	**0.370**	**0.725**	**0.195**	**2.029**	**0.203**	**0.136**
RD	RD1	70.40 **A**	5.39 **B**	9.90 **C**	41.94	1 878.98 **B**	30.13 **B**	13.44
	RD2	68.96 **A**	6.36 **A**	10.74 **B**	42.03	1 966.25 **A**	30.30 **AB**	13.53
	RD3	66.13 **B**	5.84 **B**	11.70 **A**	42.06	1 968.39 **A**	30.48 **A**	13.74
LSD 0.05		**2.403**	**0.453**	**0.863**	**0.239**	**0.239**	**0.248**	**0.166**
N	N1	61.92 **B**	5.42 **B**	9.39 **B**	41.37 **C**	1 641.09 **D**	30.21	12.90 **C**
	N2	70.29 **A**	5.49 **B**	9.59 **B**	41.99 **B**	1 863.31 **C**	30.43	13.46 **B**
	N3	72.13 **A**	6.21 **A**	11.99 **A**	42.39 **A**	2 152.45 **A**	30.35	13.89 **A**
	N4	69.64 **A**	6.34 **A**	12.14 **A**	42.29 **A**	2 094.65 **B**	30.22	13.80 **A**
LSD 0.05		**2.774**	**0.524**	**0.997**	**0.276**	**0.239**	**0.287**	**0.192**

Means with similar letters within each column for each treatment are not significantly different (Duncan 5%).

These results had a good line with data reported by researchers [10, 13, 18, 20, 21] who reported that the use of nitrogen could increase safflower 1000-seed weight.

As seen in Fig. 3, the interaction effect of Y and RD in 1000-seed weight was statistically significant at the 5 % probability level and the highest was obtained in Y1 x RD2 as 42.43g and the lowest mean value was 41.70 and 41.73g from Y2 x RD2 and Y2 x RD1, respectively (Table 5).

TABLE V
THE MEANS OF MULTIPLE COMPARISON TEST OF DUNCAN FOR THE EFFECTS OF BILATERAL AND TRILATERAL INTERACTIONS OF THE MAIN FACTORS ON QUANTITATIVE CHARACTERS OF SAFFLOWER

Interractions			Plant height (cm)	Main branches per plant	Head number per plant	1000-seeds weight (g)	Seed yield (kg ha^{-1})	Seed oil content (%)	Seed Protein content (%)
Y x RD	RD1	Y1	74.72	5.41	9.95	42.15 a	2003.25	30.32	13.26
		Y2	66.08	5.36	9.86	41.73 b	1754.72	29.94	13.62
	RD2	Y1	75.09	6.40	11.77	42.43 a	2103.63	30.45	13.32
		Y2	62.83	6.33	11.63	41.70 b	1828.87	30.16	13.73
	RD3	Y1	71.23	6.18	11.39	42.01 ab	2102.97	30.86	13.37
		Y2	61.02	5.50	10.08	42.05 ab	1833.82	30.09	13.78
Y x N	N1	Y1	62.77	5.45	9.45	41.67	1664.12 cd	30.43	12.70
		Y2	61.07	5.38	9.33	41.06	1618.07 d	29.98	13.09
	N2	Y1	74.39	5.54	9.69	42.26	1917.27 abc	30.67	13.26
		Y2	66.19	5.43	9.48	41.72	1809.36 bcd	30.20	13.67
	N3	Y1	80.32	6.42	12.41	42.50	2382.37 a	30.61	13.68
		Y2	63.93	5.99	11.58	42.29	1922.52 cd	30.09	14.11
	N4	Y1	77.24	6.57	12.60	42.35	2316.05 ab	30.46	13.63
		Y2	62.04	6.11	11.68	42.24	1873.26 cd	29.99	13.97
RD x N	RD1	N1	62.43	4.87	8.43	41.31	1608.39	29.83	12.78
		N2	68.74	5.18	9.05	41.93	1809.90	30.18	13.35
		N3	77.71	5.90	11.41	42.23	2071.12	30.17	13.85
		N4	72.72	5.60	10.72	42.30	2059.90	30.33	13.78
	RD2	N1	63.22	5.62	9.75	41.43	1652.02	30.20	12.78
		N2	72.59	5.98	10.45	42.07	1875.37	30.59	13.35
		N3	70.57	6.59	12.72	42.64	2212.92	30.49	13.85
		N4	69.45	7.26	13.88	42.11	2124.74	29.94	13.78
	RD3	N1	60.12	5.76	9.25	41.36	1662.89	30.59	12.97
		N2	69.53	5.30	10.00	41.97	1904.67	30.53	13.40
		N3	68.10	6.13	11.86	42.31	2173.31	30.39	13.79
		N4	66.75	6.16	11.83	42.47	2132.69	30.40	13.94

Means with similar letters within each column for each treatment are not significantly different (Duncan 5%).
Y1: 2011; Y2: 2012; RD1: 10 cm; RD2: 15 cm; RD3: 20 cm; N1: 0 kg ha^{-1}; N2: 100 kg ha^{-1}; N3: 150 kg ha^{-1}; N4: 200 kg ha^{-1}

E. Seed yield

The simple effect of years, which had different climatic conditions on seed yield was highly significant (1%) (Table 3). The maximum seed yield (2069.95 kg ha^{-1}) obtained in 2011 and minimum seed yield (1805.81 kg ha^{-1}) obtained in 2012.

The results of analysis of variance (Table 3) revealed that row distances (plant density) had highly significant (1%) effects on seed yield. The seed yield varied from RD1 and RD3, where the highest and lowest seed yield (1968.39 and 1878.98 kg ha^{-1}) were obtained in both plots RD3 and RD1, respectively (Table 4).

This increase in seed yield may be due to contribution of various yield and growth parameters which were higher at wider row distances. The results agreed with the findings of by Kolsarici and Güney [12] and Oad, Samo [15]. Nitrogen fertilization positively affected seed yield till an optimum nitrogen rate. On the bases of this, there was a highly significant (1%) increase in seed yield by increasing N rates (Table 3). Maximum seed yield (2152.45 kg ha^{-1}) obtained from the pilots where N3 (150 kg N ha^{-1}) was applied and minimum seed yield (1641.09 kg ha^{-1}) obtained by applying 0 kg N ha^{-1} (Table 4). Generally, in most previous studies seed yield was increased by N fertilization at different rates depending on the experimental methods. Present results had a good line with the previous study of Bitarafan, Shirani-Rad [10], Mohamed, Jellings [18] and Eryiğit, Akiş [22] who reported that the use of nitrogen could increase safflower seed yield.

The results of analysis of variance (Table 3) showed that the interaction between years and nitrogen rates was highly significant (1%) for seed yield. According to the means comparison (Table 5), the highest and lowest seed yield obtained in N3Y1 (2382.37 kg ha^{-1}) and N1Y2 (1618.07 kg ha^{-1}), respectively (Fig. 4).

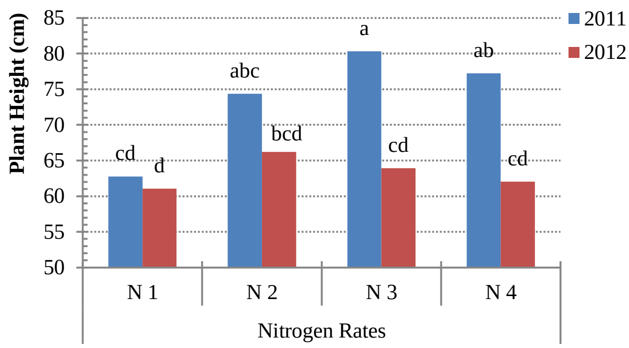

Fig. 1. The effects of the bilateral interaction of Y x N on plant height

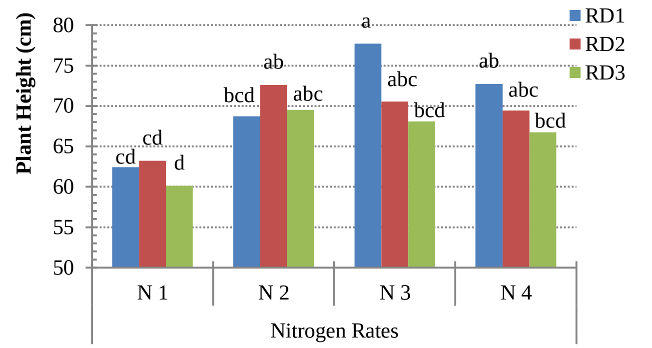

Fig. 2. The effects of the bilateral interaction of RD x N on plant height

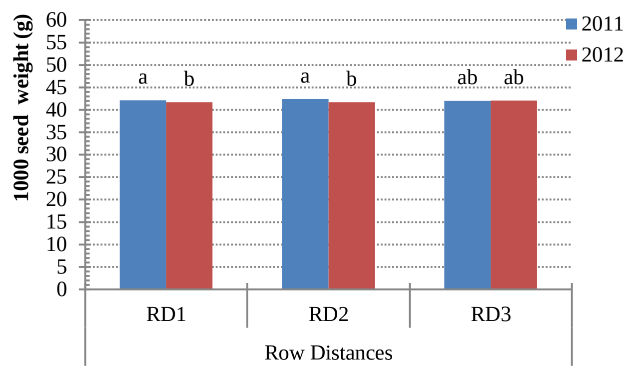

Fig. 3. The effects of the bilateral interaction of Y x RD on 1000 seed weight

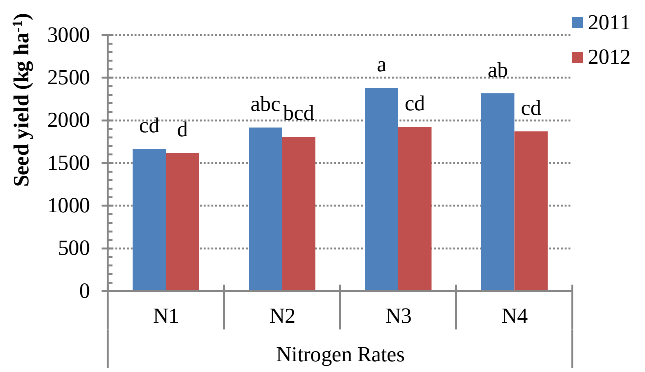

Fig. 4. The effects of the bilateral interaction of Y x N on seed yield

F. Seed oil content

Seed oil content was influenced significantly (1%) by simple effects of the years (Table 3). The highest and lowest values of seed oil content (30.54 and 30.06%) were obtained in 2011 and 2012, respectively (Table 4).

As screened on Table 3, seed oil content was affected significantly (5%) by row distances. The highest oil content (30.48%) was determined from RD3 and the lowest oil content (30.13%) was obtained from RD1, respectively (Table 4). The recent results confirm the findings of Oad, Samo [15] who reported that the increasing distance within plants significantly increased oil content of seed.

The reaction of the seed oil content to nitrogen rates was not found statistically significant (Table 3). Oil content values According to the two-year averages, the protein contents (13.44, 13.53 and 13.74%) were recorded. 30.21; 30.43; 30.35 and 30.22% were obtained from N1; N2; N3 and N4 rates, respectively (Table 4). The results coincided with many researchers' findings who did not find any relationship between rates of nitrogen and oil content [9], [20] and [17]. Likewise, Katar, Arslan [14] stated that the high N rates applied to safflower slightly decreased oil content.

G. Seed protein content

The data of results in Table 3 there were statistical (1%) differences between years for protein content. The higher and lower protein contents of (13.71%) and (11.32%) were recorded at 2012 and 2011, respectively.

The results revealed that, safflower crop sown at different row distances had no significant effects on protein content.

The variation among nitrogen rates was statistically significant (1%) for protein content (Table 3). According to the Duncan's multiple range test, results showed that higher and lower protein contents (13.89%) and (12.90%) were recorded at N3 (150 kg N ha^{-1}) and N1 (0 kg N ha^{-1}), respectively. For each successive increase of nitrogen rates up to N3 (150 kg N ha^{-1}), there was a significant increase in protein content. The results confirm the findings of Mündel, Blackshaw [23] and Abd El- Mohsen and Mahmoud [3] who reported nitrogen applications effect positively the protein content of safflower seed.

IV. Conclusion

Row distances (plant density) and Nitrogen fertilizer are two important factors in crop management for optimizing productivity. There is a variation between the response of crops to different row distances and nitrogen rates. The row distances and nitrogen rates significantly affected some important growth, yield and yield components of safflower. According to the results, in order to cultivate safflower as an oil crop in conditions similar to the region of this experiment, application of 30 cm row distance and 150 kg N ha^{-1} for the highest return unit area were recommended.

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