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The influence of nitrogen doses on yield and yield properties of safflower (*Carthamus tinctorius*) varieties under micro-climate conditions of Igdir plain – Turkey

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ABSTRACT

The growth and development of safflower are affected by several factors such as genotype, agronomic practices, and environmental conditions. One of the most important agronomic practices is fertilization. As a fertilizer, nitrogen is a basic element required for successful plant growth. In the study, it was aimed to determine the effects of different nitrogen doses (0, 100, 150, and 200 kg ha^{-1}) on yield and yield properties of three safflower varieties (Remzibey-05, Dinçer, and Yenice) under micro-climate conditions in the Iğdır University Agricultural Research fields, Turkey during 2012 – 2013 according to the split-plot experimental design in randomized blocks with three replications. The investigation denoted that the differences among the varieties were found significant for all attributes except seed number per head. And also, the effect of differences between observation years and the effects of nitrogen rates were determined to be significant for all observed properties. Increasing the nitrogen rate increased all observed attributes. Seed oil content increased with nitrogen applications up to 100 kg ha^{-1} but reduced again in higher nitrogen rates. In the study, the interactions of both factors had no significant effects on all observed attributes. The results of two years study show that the Yenice safflower cultivar as an alternative oil plant and the most economical nitrogen dose of 150 kg ha^{-1} can be suggested for the maximum yield in the unit area where the experiment is carried out and in other regions with similar climatic conditions.

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microclimate; nitrogen; safflower; variety; yield

Introduction

A typical plant of the genus Compositae or Asteraceae safflower (*Carthamus tinctorius* L.) is a significant oilseed crop, which is a highly branched, herbaceous, thistle-like annual plant (Eslam, Monirifar, and Ghassemi 2010; Khalil, Dagash, and Yagoub 2013) adapted to Turkey. Safflower, which is not very selective in terms of climate and soil, is an oilseed plant with an important potential in both human and animal feeding (Gümüş and Küçükersan 2016). It can be successfully cultivated in both dryland and irrigated areas. It has resistance to saline conditions (Fraj

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et al. 2013) and drought stresses (Bassil and Kaffka 2002; Eslam, Monirifar, and Ghassemi 2010). Therefore, it can be used to narrow down fallow fields in arid areas.

Traditionally, safflower, particularly before cheaper amino alkane dyes became on the market, was cultivated for its seeds, and used for coloring and flavoring the foods, manufacturing drugs, and creating red (carthamin) and yellow paints (Cho and Hahn 2000), but for the past fifty years, the plant has been grown mainly for edible oil extracted from its seeds (Omidi and Sharifmogadas 2010). Additionally, safflower is an important alternative food material that can be used as animal feed or roughage feed, and as concentrate feeds with seed and oil as well as rich in residual protein after the oil is obtained (Landau et al. 2005; Oelke et al. 2013). Today, as the need for food and the share of biofuels in energy production increases, the demand for oilseeds plants such as soybean sunflower, and corn are increasing, and accordingly, the prices of these products are rising. Therefore, safflower is an important alternative to these products for both human and animal consumption (Gümüş and Küçükersan 2016).

The safflower oil contains nearly %77 (linoleic) polyunsaturated fatty acid, which is significantly higher than corn cottonseed, peanut, soybean, and olive oils. This kind of safflower oil is used principally for eatable oil products such as soft margarine and salads oils. The fact that it contains high-quality edible oil and the interest of the public has made safflower a very important vegetable oil crop (Oelke et al. 2013). In addition, due to the richness of the unsaturated fatty acids used in the conjugated linoleic acid (CLA) synthesis, safflower plants have a separate prescription for ruminants. Therefore, especially safflower is considered as a feedstock that can be used to increase the amount of linoleic and oleic acid and meat and poultry CLA (Gümüş and Küçükersan 2016).

The oleic types of safflower varieties can function in a heat-resistant manner. As an industrial oil, it can be considered a drying or semi-drying oil used in the production of paints and different surface coatings. This oil can be substituted for fossil fuels, but like many vegetable oils, it is currently very valuable for this use (Oelke et al. 2013).

Vegetable oil production within the world is mainly covered by palm oil, soybean, rapeseed, and sunflower. The majority of vegetable oil production in Turkey is obtained from sunflower. In addition to cottonseed, soybeans, rapeseed, safflower, olive, and corn crops are used to produce vegetable oils. However, the most widely grown and produced one is the sunflower. Therefore, only sunflowers account for 69% of vegetable oil production, 84% of total oil consumption, and 32% of total oil use. However, the maximum production area has been reached. Since oil production does not meet domestic consumption, a large proportion of oil demands are imported. Therefore, safflower, which has low production, may be the hope of covering the vegetable oil gap.

In this study, it was aimed to determine the effects of nitrogen doses on yield and yield properties of different safflower varieties in order to increase yield and reduce environmental problems in Igdir.

Material and methods

The research was conducted at 39° 55′ N latitude, 44° 5′ E longitude and 851 m altitude under microclimate conditions of Iğdı r Plain in 2012 and 2013 in the experimental areas of Iğdı r University Agricultural Research and Training Center, Iğdır, Turkey.

Soil sample analyzing and climatic conditions

The soil specimens of the trial field were taken at 0-30 cm depth before the sowing and analyzed for some characteristics that are monitored in Table 1.

Table 1. Some characteristics of trial field soil (0-30 cm depth).

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	1.91	7.98	11.59	0.99	2.13	35	263

Table 2. The recorded data for the trial periods in 2012 and 2013.

	Average monthly temp. (°C)			Precipitation (mm)			Average relative humidity (%)		
Months	2012	2013	LT	2012	2013	LT	2012	2013	LT
April	17.8	15.4	13.3	16.2	3.1	37.6	52.0	46.8	49.4
May	21.0	18.9	17.6	57.4	4.2	48.8	63.0	52.5	51.2
June	26.5	23.3	22.2	26.7	3.1	32.2	31.0	43.7	47.3
July	27.2	26.5	26.0	23.0	1.5	14.3	89.0	37.7	44.7
August	29.8	25.4	25.2	0.6	2.7	9.6	70.0	41.6	46.7
September	22.7	21.3	20.1	29.3	1.6	10.0	80.0	43.2	51.0

Climate data of Iğdır Meteorology Directorate.

As shown in Table 2, monthly average temperatures during the farming season (April-September) in 2012 were almost equal to long-term data, while the average of 2013 was higher than long-term data. The monthly average temperatures showed similarity with both years but contradicted between growth stages. The higher temperatures were observed in the generative stages in both years. While the total rainfall (250.1 mm) in 2012 was over long-term data (152.5 mm), the total precipitation in 2013 was almost consistent with long-term data. The variations were monitored among the monthly rainfalls during the 2012 and 2013 growing stages. The crops received higher precipitation in April-July (vegetative stages) in 2012 than in 2013. The mean humidity rate in 2012 (49.0%) was almost analogous with that (48.4%) in the long term, while the average humidity rate in 2013 (64.2%) was over data of both 2012 and long-term.

Experimental design and measurements

The study was conducted according to the split-plot experimental design in randomized blocks with three replications. Each block has consisted of three safflower varieties in main plots and 4 nitrogen (N) doses (Ammonium Sulfate (21% N); 0 kg ha^{-1}, 100 kg ha^{-1}, 150 kg ha^{-1}, and 200 kg ha^{-1}) in subplots. Each plot was adjusted 1.5 m wide and 5 m long. The distances were 2 m between the main plots and 1 m between the subplot, which was comprised of five rows 30 cm apart. Dinçer, Remzibey-05, and Yenice cultivars were used as materials. In the study, half of the nitrogen doses, and 100 kg ha^{-1} of Triple Super Phosphate (46% P_2O_5) were treated to the subplots after parcellation of the field for the study. The sowings were completed on 04.05.2012 and 15.05.2013. After germination, seedlings were singled to be 15 cm in-row range, and weeds control was performed by hand as far as required.

In the study, yield and yield properties such as plant height, number of main branches, head diameter, number of heads per plant, thousand seed weight, seed yield, and seed oil content were observed on randomly selected 15 plants from three middle rows after deleting 50 cm of both top and bottom in each plot.

Statistical data analysis

After all measurements and analyzes were completed, the data obtained were subjected to variance analysis. The variance analysis of data for each observed attribute was computed according to the split-plot experimental design in randomized blocks by using the IBM SPSS (v. 22.0). The

"Duncan multiple range test (MRT)", a multiple comparison test, was used to compare sets of means at a 5% probability level. For observing the interaction effects among the treatments MSTATC software package was used. The correlation analysis of the observed parameters was calculated according to the Spearmen equation by IBM SPSS v 23.0.

Results and discussion

The results and mean comparisons for yield, yield properties, and oil contents are demonstrated in Tables 3.

The determined effects of nitrogen fertilizer doses on plant growth and yield properties

Plant height

As a result of the study, the years, varieties, and nitrogen doses were statistically significant ($p < 0.01$) in terms of the effects of different nitrogen doses on plant height of different safflower varieties.

The average plant height (151.3 cm) measured in 2012 was higher than the average plant height (138.4 cm) determined in 2013 (Table 3). These differences may have resulted from climate, environmental conditions, and cultural practices. In growing seasons, sufficient precipitation, temperature increase, lighting intensity, daylight time, latitude, and longer photoperiods can increase plant heights. It was significantly affected by different nitrogen application rates (Table 3). The highest plants (93 cm) were recorded from the Yenice cultivar. It was determined that the nitrogen dose of 150 kg ha^{-1} produced the highest plant height (91.87 cm) while the lowest plant height observed from control plots as 78.85 cm (Table 3). This increase in plant height parallel to the increase in nitrogen doses may be related to the influence of nitrogen supported vegetative growth associated with other growth factors. These results are in harmony with the report of Tigre, Worku, and Haile (2014).

Number of main branches

According to the results, the effects of the years, varieties, and nitrogen doses on the number of main branches were found to be statistically significant ($p < 0.01$). In terms of years, the higher number of main branches was monitored as 9.15 in 2012 (Table 3). The reason for this important difference between years can be said to be caused by climate difference. The results show that the genotypic difference of the varieties caused the number of the main branches in the plant to be different. The highest and lowest numbers of main branches were counted for Yenice and Remzibey as 9.27 and 8.36, respectively. The application of nitrogen at the dose of N3 (150 kg ha^{-1}) yielded the highest number of branches (9.92), while the control plots produced the lowest number (7.55) (Table 3). These findings are in good harmony with the results of previous studies reported by Elfadl et al. (2009) and Mohamed, Jellings, and Fuller (2012).

Number of heads per plant

In the study, the influence of the years, varieties, and nitrogen doses on the head numbers were found to be statistically significant ($p < 0.01$). It was observed that the number of heads had a higher average value (19.14) in 2012 than (18.14) in 2013. The stress caused by the high climatic conditions in the reproductive growth period in 2013 has negatively influenced the number of branches per plant, which could have decreased the number of heads per plant. The highest number of heads per plant (20.30) was being counted in Yenice, while the lowest value (17.70) was observed in Dinçer variety (Table 3). Generally, the head numbers are determined by the branch numbers in the safflower plants. Because almost every branch ends with a head. The highest value

Table 3. Comparisons of the effects of the years, varieties, and doses of nitrogen on some properties of safflower.

Factors		Plant height (cm)		Number of main branches		Number of heads per plant		Head diameter (cm)		Number of seeds per head		Thousand seeds weight (g)		Seed yield (kg ha^{-1})		Seed oil content (%)
Year (Y)	Y1	88.04	A	9.15	A	19.14	A	2.21	A	45.51	A	33.16	A	2297.2	A	30.62	A
	Y2	83.46	B	8.67	B	18.14	B	2.11	B	43.43	B	31.63	B	2176.3	B	29.22	B
	Average	85.75		8.91		18.64		2.16		44.47		32.40		2236.8		29.92	
Variety (V)	Dincer	90.78	B	8.39	B	17.70	B	2.09	B	44.85		31.88	B	2123.4	B	29.99	A
	Remzibey	72.96	C	8.36	B	17.92	B	2.11	B	43.16		33.36	A	2150.9	B	30.39	A
	Yenice	93.50	A	9.27	A	20.30	A	2.29	A	45.40		31.95	B	2435.9	A	29.39	B
	Average	85.75		8.67		18.64		2.16		44.47		32.40		2236.8		29.92	
Nitrogen (N)	N1	78.85	D	7.55	C	16.15	C	2.02	C	37.58	C	31.99	B	1938.1	C	29.67	B
	N2	83.95	C	8.70	B	18.06	B	2.16	B	42.99	B	32.51	A	2167.0	B	30.36	A
	N3	91.87	A	9.92	A	20.60	A	2.26	A	49.05	A	32.73	A	2472.0	A	29.98	AB
	N4	88.32	B	9.47	A	19.75	A	2.22	A	48.27	A	32.36	AB	2369.9	A	29.68	B
	Average	85.75		8.91		18.64		2.16		44.47		32.40		2236.8		29.92	
	CV	4.08		8.82		7.73		3.88		3.30		2.15		7.73		2.59	

A–D capital alphabets mean in each column for each factor followed by the same letter are not significantly different (Duncan test. %5).

Table 4. The coefficient values of correlation for Safflower varieties affected by different nitrogen doses each year.

Observed Properties	YEAR	PH	NMB	NHPP	HD	SNPH	TSW	SY	SOC
Plant height (PH)	2012	1	0.110	0.116	0.110	−0.245	−0.431**	−0.246	−0.484**
	2013		0.117	0.124	0.092	−0.239	−0.430**	−0.244	−0.481**
Number of main branches (NMB)	2012		1	0.996**	0.258	0.280	0.214	0.291	0.411*
	2013		1	0.996**	0.247	0.268	0.181	0.281	0.395*
Number of heads per plant (NHPP)	2012			1	0.286	0.266	0.216	0.274	0.393*
	2013			1	0.277	0.257	0.186	0.266	0.377*
Head diameter (HD)	2012				1	0.567**	0.243	0.596**	0.086
	2013				1	0.562**	0.285	0.592**	0.101
Seed number per head (SNPH)	2012					1	0.480**	0.992**	0.437**
	2013					1	0.470**	0.992**	0.433**
Thousand seeds weight (TSW)	2012						1	0.476**	0.731**
	2013						1	0.477**	0.733**
Seed yield (SY)	2012							1	0.462**
	2013							1	0.463**
Seed oil content (SOC)	2012								1
	2013								1

*The correlation is significant at the %5 level.
**The correlation is significant at the %1 level.

of the head numbers (20.60) was counted from the plots where 150 kg ha^{-1} was applied while the lowest value (16.15) was monitored in the control plots (Table 3). The results of the study are consistent with findings reported by Bitarafan, Shirani-Rad, and Delkhosh (2011).

Head diameter

Due to the significant ($P < 001$) diverse effects of climatic conditions in 2012 and 2013 on the diameter of the heads, while the highest value (2.21 cm) was achieved in 2012, the lowest value (2.11 cm) was measured in 2013 (Table 3). The significant differences ($P < 0.01$) among the varieties caused the head diameters to be different. The largest head in diameter (2.29 cm) was observed from Yenice and the tiniest was achieved from (2.09 cm) from Dinçer, respectively (Table 3). In the study, it was determined that the effects of different nitrogen doses were statistically significant ($P < 001$) on diameters of heads. The highest values (2.22-2.26 cm) were measured in plots treated with N3 and N4 while the lowest value (2.02 cm) was monitored from control (Table 3). The results show a similarity with the study results of Bitarafan, Shirani-Rad, and Delkhosh (2011).

Number of seeds per head

According to the results of the study, the effects of the years and nitrogen doses on the number of seeds per head were determined to be statistically significant ($p < 0.01$). When Table 3 was evaluated in terms of the years, while the highest seed number (45.51) was counted in 2012, the lowest value (43.43) was observed in 2013. In the study, it was seen that there were no statistically significant ($P > 0.05$) differences in the number of seeds per head among varieties. The numbers of seeds per head were counted as 44.85 in Dinçer, 45.40 in Yenice, and 43.16 in Remzibey, respectively (Table 3). In Table 3, N3 and N4 doses produced the highest numbers of seeds as 49.05 and 48.27, whereas the control plots produced the lowest number (37.58). This character is mainly determined by the head diameter in the safflower plants.

Thousand seed weight

The study results showed that the influence of the years, varieties, and nitrogen doses on thousand seed weight were found to be statistically significant ($p < 0.01$ for years and varieties, $P < 0.05$ for nitrogen doses). The maximum weight (33.16 g) was determined in 2012 (Table 3).

When the averages of varieties were examined from Table 3, the maximum (33.36 g) and minimum (31.38 g and 31.95 g) thousand seed weights were observed for Remzibey, Dinçer, and Yenice, respectively. In terms of nitrogen doses, the highest thousand seed weight values (32.51 g and 32.73 g) were obtained in the plots that were treated with N2 and N3, while the lowest value (31.99 g) was obtained from the control (Table 3). These results of the study are consistent with findings previously declared by Khalil, Dagash, and Yagoub (2013) and Mohamed, Jellings, and Fuller (2012).

Seed yield

In the study, it was observed that the effects of the years, variety, and nitrogen ratios were statistically significant ($p < 0.01$) on the seed yield of safflower. The yield varied significantly between the two years. In 2013, Iğdır climate conditions caused significant decreases in seed yield compared to 2012, especially due to insufficient precipitation and high temperatures during the critical breeding period (Tables 1 and 3). The highest seed yield (2297.2 kg ha^{-1}) was achieved in 2012. The reason for this increase in safflower seed yield may be due to the positive correlation between the number of heads per plant, head diameter, number of seed per head, and thousand seed weight, which benefited better than nitrogen under favorable climatic conditions of 2012. When Table 3 is analyzed in terms of cultivars, while the maximum seed yield (2435.9 kg ha^{-1}) was obtained from Yenice, minimum values were observed from the other two varieties that were not statistically different (Table 3). This difference may have resulted from three major genotypic features in safflower plants, especially the number of heads per plant, the number of seeds per plant, and the weight of one thousand seeds. Kolsarici and Eda (2002) and Oad et al. (2001) roughly declared similar results in their previous researches. In the study, the highest seed yields (2369.9 and 2472.0 kg ha^{-1}) were weighed from N3 and N4 doses, while the lowest value (1938.1 kg ha^{-1}) was achieved from the control plots. A difference of 18.22% was detected between the highest and lowest seed yields. The study findings were found to be compatible with the findings of Bitarafan, Shirani-Rad, and Delkhosh (2011) and Mohamed, Jellings, and Fuller (2012), who reported that using nitrogen up to a certain dose could increase the yield of safflower.

Seed oil content

It was observed from the results that the effects of the years, varieties, and nitrogen doses on seed oil content were found to be statistically significant ($p < 0.01$ for years and $P < 0.05$ for varieties, nitrogen doses). The maximum and minimum seed oil contents were achieved in 2012 and 2013 as 30.62 and 29.22%, respectively (Table 3). The highest seed oil contents were observed from Dinçer and Remzibey as 29.99 and 30.39%, respectively. In terms of nitrogen doses, the maximum oil content (30.36%) was obtained from N2 (Table 3). The results were slightly different from the previous studies of Kolsarıcı, Alluşoğlu, and Kaya (2005), who could not find any relationship between oil content and applied nitrogen doses.

Correlation analysis

As can be seen in Table 4, it has been determined that the relationships between the examined features do not differ by years. From the point of view of seed yield, it was observed that all the studied characteristics, except the plant height, the number of branches, and the number of heads, which have a neutral effect, have a significant positive relationship with seed yield at the level of 1%. In terms of seed oil content, all the features examined were significantly (%5 and %1) positive related to seed oil content, except for plant height with a strongly negative (%1) effect and table diameter with a neutral effect in both years. Therefore, it can be estimated that the increase

in the value of the observed plant characters positively affects the seed yield. Campbell et al. (1993) reported that multiple regression should be performed to relate grain yield, number of grains, seed index, and other crop features.

Conclusion

The amount of useful nitrogen in the soil has a significant effect on growth, yield, and yield properties in the safflower plants, as in most plant species. A significant part of the Iğdır plain soils are insufficient in terms of nitrogen necessary for plant growth. This deficiency can be overcome by fertilizer use, but there is unconsciously nitrogenous fertilizer use above or below the amount available in plants. Based on this point of view, according to the results of the study of two years, it can be recommended that Yenice safflower variety as an alternative oil plant for maximum yield in the unit area, and 150 kg ha^{-1} which is determined as the most economical nitrogen dose for growing in the Iğdır plain and other regions with similar climatic conditions.

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References

Bassil, E. S., and S. R. Kaffka. 2002. Response of safflower (*Carthamus tinctorius* L.) to saline soils and irrigation. I. Consumptive water use. *Agricultural Water Management* 54 (1):67–80. doi: 10.1016/S0378-3774(01)00148-2.

Bitarafan, Z., A. H. Shirani-Rad, and B. Delkhosh. 2011. Nitrogen rates and sowing date effect on yield and oil content of spring safflower. *International Journal of Science and Advanced Technology* 1 (6):25–30.

Campbell, C. A., F. Selles, R. P. Zentner, and B. G. McConkey. 1993. Available water and nitrogen effects on yield components and grain nitrogen of zero-till spring wheat. *Agronomy Journal* 85 (1):114–20. doi: 10.2134/agronj1993.00021962008500010022x.

Cho, M. H., and T. R. Hahn. 2000. Purification and characterization of precarthamin decarboxylase from the yellow petals of *Carthamus tinctorius* L. *Archives of Biochemistry and Biophysics* 382 (2):238–44. doi: 10.1006/abbi.2000.1984.

Elfadl, E., C. Reinbrecht, C. Frick, and W. Claupein. 2009. Optimization of nitrogen rate and seed density for safflower (*Carthamus tinctorius* L.) production under low-input farming conditions in temperate climate. *Field Crops Research* 114 (1):2–13. doi: 10.1016/j.fcr.2009.06.012.

Eslam, B. P., H. Monirifar, and M. T. Ghassemi. 2010. Evaluation of late season drought effects on seed and oil yields in spring safflower genotypes. *Turkish Journal of Agriculture and Forestry* 34 (1):373–80.

Fraj, M. B., A. J. Al-Dakheel, I. R. McCann, G. M. Shabbir, G. A. Rumman, and A. Q. A. M. Al Gailani. 2013. Selection of high yielding and stable safflower (*Carthamus tinctorius* L.) genotypes under salinity stress. *Agricultural Science Research Journal* 3 (9):273–83.

Gümüş, E., and S. Küçükersan. 2016. The use of safflower in ruminant nutrition. *Livestock Studies* 56 (1):25–31.

Khalil, N. A. A., Y. M. Dagash, and S. O. Yagoub. 2013. Effect of sowing date, irrigation intervals and fertilizers on safflower (*Carthamus tinctorius* L.) yield. *Discourse Journal of Agriculture and Food Sciences* 1 (5):97–102.

Kolsarici, O., and G. Eda. 2002. Effects of different row distances and various nitrogen doses on the yield components of a safflower variety. *Sesame and Safflower Newsletter* 2002 (17):108–11.

Kolsarıcı, Ö., S. Alluşoğlu, and M. D. Kaya. 2005. The effects of tillage and nitrogen doses on water use efficiency, soil moisture and seed characters of safflower (*Carthamus tinctorius* L.) in wheat-safflower rotation system. Paper Read at Proceedings of the VIth International Safflower Conference, İstanbul-Turkey, 6–10 June, 2005. SAFFLOWER: A Unique Crop for Oil Spices and Health Consequently, a Better Life For You.

Landau, S., G. Molle, N. Fois, S. Friedman, D. Barkai, M. Decandia, A. Cabiddu, L. Dvash, and M. Sitzia. 2005. Safflower (*Carthamus tinctorius* L.) as a novel pasture species for dairy sheep in the Mediterranean Conditions of Sardinia and Israel. *Small Ruminant Research* 59 (2–3):239–49. doi: 10.1016/j.smallrumres.2005.05.008.

Mohamed, S. J., A. J. Jellings, and M. P. Fuller. 2012. Effect of nitrogen on safflower physiology and productivity. *African Crop Science Journal* 20 (4):225–37.

Oad, F. C., M. A. Samo, S. M. Qayyum, and N. L. Oad. 2001. Inter and intra row spacing effect on the growth, seed yield and oil content of safflower *Carthamus tinctorius* L. *Asian Journal of Plant Sciences* 1 (1):18–9. doi: 10.3923/ajps.2002.18.19.

Oelke, E. A., E. S. Oplinger, T. M. Teynor, D. H. Putnam, J. D. Doll, K. A. Kelling, B. R. Durgan, and D. M. Noetzel. 2013. *Safflower*. http://www.hort.purdue.edu, http://www.hort.purdue.edu/newcrop/afcm/safflower.html.

Omidi, A. H., and M. R. Sharifmogadas. 2010. Evaluation of Iranian safflower cultivars reaction to different sowing dates and plant densities. *World Applied Sciences Journal* 8 (8):953–8.

Tigre, W., W. Worku, and W. Haile. 2014. Effects of nitrogen and phosphorus fertilizer levels on growth and development of barley (*Hordeum vulgare* L.) at Bore district, Southern Oromia, Ethiopia. *American Journal of Life Sciences* 2 (5):260–6. doi: 10.11648/j.ajls.20140205.12.