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Full Length Research Paper

Effect of nitrogen and iron fertilizers on seed yield and yield components of safflower genotypes

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Nitrogen and Iron fertilizers are considered as important elements in plant nutrition. This experiment was carried out via factorial split plot design based on randomized complete blocks design with three replications. Nitrogen rates were arranged as the main factor with three levels (0, 75 and 150 kg/ha) and iron spraying (sulphate of iron) with two levels (1/1000 and 2/1000) (kg/1000 L H_2O) along with 10 safflower genotypes including four lines (22-191, V-138, Isfahan14, Isfahan 28) and six landraces (Golsefid, Goldasht, Arak, Isfahan, Shiraz and kashan) as subfactor. Analysis of variance showed that the highest content of seed yield and its components (head number/plant, seed number/head, 1000 – seed weight) and harvest index were obtained from application of 100 kg/ha nitrogen treatment and sulphate of iron that was sprayed with 2/1000 dose (kg/1000 L H_2O) in Shiraz landrace. Based on correlation coefficients analysis, seed yield showed positive and significant correlation with seed number/head, biological yield and harvest index. According to regression analysis, seed number/head was considered as the main trait that explained nearby 49% of total variation in seed yield.

Key words: Safflower, genotype, nitrogen, iron, seed yield.

INTRODUCTION

Oil consumption has been increased due to increasing population and capitation consumption recently (Weiss, 2000). Certainly, one of the most attentions is to cultivate oil seeds, such as safflower, because of its importance in human nutrition. Improvement of oil seeds quality and quantity has formed an important part of cultivation in different countries (Weiss, 2000). Data showed that 750000 (ton) oil is annually needed for human consumption in Iran. Oil seeds have an important role in nutritionally demands of mankind, animal feeding and medicine (Singh, 2007). Iran is one of centers of safflower origin (Knowles, 1969). The high quality oil of safflower could be used as an edible product such as salad oil, margarine, cooking and frying oil Pascual-Villalobos and Alburquerque, 1996). Generally, safflower is produced on marginal lands that are relatively dry and deprived of the benefits of fertilizer inputs. Attempts to improve seed yield and quality by developing new cultivars and agronomic practices are underway throughout the world. Since Iran is located in an arid region where some abiotic stresses such as salinity and drought are prevalent, safflower can be a candidate crop in dry land agro-ecosystems, due to its potential for growth under water stress and the economical value in terms of both oil and seed (Yau., 2004).

Nitrogen compounds are important in plant chemical compounds such as protein, nucleic acid, chlorophyll and enzymes structure (Herdrich, 2001). It has an important role in the tissues structure of plants (Herdrich, 2001). Therefore, the determination of the most suitable dose of nitrogen fertilizer will increase the seed yield of safflower. Iron is one of the members of electron conductivity. Iron and molybdenum are one of the important elements of nitrate, nitrate reductase and nitrogenase enzyme and also, it could fix nitrogen (Khajeh-Poor, 2005). Nitrogen deficiency reduces plant amino acid content as the basic element for the construction of amino acids and proteins (Berglund et al., 1998; Herdrich, 2001). Iron (Fe) is a member of the electron transmitter enzymes for example cytochrome and ferredoxin (Marschner, 1995). It is active

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in photosynthesis and respiration. Fertilizer application represents an important measure to correct nutrient deficiencies and to replace elements removed in the products harvested, and N fertilization has been shown to be particularly effective with respect to yield formation (Connor and Sadras, 1992).

The effect of nitrogen fertilizer has been studied on improvement of seed yield and its components in safflower (Abel, 1974; Haby et al., 1982; Heidari and Asad, 1998; Abbadi et al., 2008). Nitrogen fertilization can increase the yield components and especially the number of heads per plant and the seed weight per plant (Dordas and Sioulas, 2008). The weight of seeds per head can be increased with N application as it was observed in other studies (Heidari and Asad, 1998; Dordas and Sioulas, 2008). In addition, N that was taken up was translocated to the seeds or to the heads and might have affected the photoassimilates distribution in the plant (Dordas and Sioulas, 2008). Safflower seed yield is affected by agronomic factors such as macro and micronutrient, water and planting distance (Taiping et al., 1993). Safflower requires deep soils and neutral pH and prefer medium soil texture (Dahnke et al., 1992). According to triennial experiments, consumption of nitrogen fertilizer increased significantly seed yield and seed yield components including members (heads per plant, seed number/head and 1000-seed weight) (Soleymani, 2005). Nitrogen fertilizer has a significant effect on increasing seed yield and its components The effect of some micronutrients like iron and nitrogen was studied in safflower (Singh and Singh, 1980; Sary et al., 2002; Ravi et al., 2008).

However, soil testing and fertilizer recommendations, including field observations are most reliable ways to achieve optimal performance (Singh and Singh, 1980). However, it seems that few fertilization experiments were conducted on the response of safflower plant yield or yield components to different rates of nitrogen and iron.

The aim of the work was to determine the effect of different contents of nitrogen and iron fertilizers on seed yield and yield components of safflower genotypes in Iran. This study could propose the best content of these fertilizers for significant improvement in seed yield and its components in safflower cultivation.

MATERIALS AND METHODS

This experiment was carried out in an experimental field of Shahid bahinar University of Kerman (56°58' longitude and 30°15', 2044 m asl), with an arid and semi-arid climate) in the Spring of 2010. The soil texture was clay-loamy with pH=7.8. The experiment was carried out as a split plot based on randomized complete block design (RCBD) with three replications. There were 60 treatment including; 10 safflower genotypes, three nitrogen rates (urea with 45% N) and two sulphate of iron (Fe_2SO_4) rates. Three nitrogen rates (50,100,150) (kg/ha) and two sulphate of iron rates (1/1000 and 2/1000) (g / 1000L of H_2O) were considered as a subfactor. Ten safflower genotypes including lines (22-191, V-138, Isfahan 14, Isfahan 28) (Golsefid, Goldasht, Arak, Isfahan, Shiraz and Kashan landaces) were considered as subfactor.

Each plot consisted of four rows 40 cm apart and 3 m length. Factors such as yield and its components (head number/plant, seed number/head, 1000-seed weight), plant height, number of branches per plant, biological yield and harvest index were evaluated. Yield components were measured on 10 randomly samples taken from the middle rows per plot. Seed yield and biological yield were assessed on the middle row of the plot after removing the border rows. After data collection, different statistical analyses including ANOVA, correlation were done using Microsoft Excel, SAS, SPSS, MSTATC software.

RESULTS AND DISCUSSION

Analysis of variance showed significant effects for nitrogen rates on SH, SY and HI (Table 1). Application of different iron ratios caused significant differences for SH and SY (Table 1). Different safflower genotypes showed significant difference for SH, SY, BY and HI (Table 1). The interaction effect of nitrogen × iron was significant for SH, SY and BY (Table 1). Interaction effect of nitrogen× genotype was significant for SY and HI (Table 1). Interaction effect of iron × genotype interaction was significant for SH, SY, BY and HI (Table 1). Also, interaction effect of nitrogen× genotype× iron was significant for SH, SY, BY and HI. Among the evaluated traits, the highest content of CV (%) was denoted to HI (Table 1). Nitrogen had an important effect on seed yield, by increasing nitrogen rates from 50 to 100 kg/ha, seed yield increased from 5.48 to 9.08 ton/ha (Table 2). Data showed that application of 100 kg/ha N had the best effect on seed yield and its components (HP, SH and SW) with PH and HI (%) (Table 2). Iron rates had significant effect on seed yield (Table 2). The highest content of seed yield (8.0 ton/ha) achieved from sulphate of iron spraying with 2/1000 dose (Table 3). Different ratios of iron and nitrogen fertilizers had different effect on different studied traits. There was significant difference among evaluated genotypes for SH, SY, BY and HI (%) (Table 4). Safflower genotypes showed significant difference for SY (Table 4). Seed yield and its components showed different responses to nitrogen and iron fertilizers. Dordas and Sioulas (2008) detected significant differences in the number of seed yield and its components under different nitrogen fertilizers.

In this study, Kashan landrace 9.67 (ton/ha) and Golsefid 4.66 (ton/ha) landraces had the highest and the least SY, among evaluated genotypes, respectively (Table 4). The highest content for BY and HI (%) was denoted to genotypes of Isfahan28 and Isfahan14, respectively (Table 4). Also, the highest and least content for SH was denoted to V-138 and Goldasht genotypes, respectively (Table 4). Other studied traits had no significant difference. The highest SY achieved from application of 100 kg/ha nitrogen and iron spraying with 2/1000 dose and the lowest content of SY from 50 kg/ha nitrogen and iron spraying with 2/1000 dose (Table 5).

Table 1. Analysis of variance of studied traits in safflower genotypes.

S.O.V.	df	PH	HP	SH	BP	SW	SY	BY	HI
Replication	2	4014.46	6.45	351.88	7.53	75.85	0.97	4.95	3.81
Nitrogen (N)	2	$6.35^{n.s}$	$1.27^{n.s}$	1664.85*	$0.59^{n.s}$	$30.54^{n.s}$	137.01**	$149.60^{n.s}$	447.80*
Iron (Fe)	1	$64.56^{n.s}$	$0.87^{n.s}$	2048.72*	$0.25^{n.s}$	$1.55^{n.s}$	33.39**	$4.48^{n.s}$	$283.89^{n.s}$
Nitrogen ×Iron	2	$379.52^{n.s}$	$2.29^{n.s}$	1729.22*	$0.26^{n.s}$	$29.55^{n.s}$	90.68**	807.01**	$219.12^{n.s}$
Residual (a)	10	143.25	10.55	570.51	2.49	30.63	1.30	73.53	100.17
Genotype	9	$80.30^{n.s}$	$5.10^{n.s}$	1257.05**	$0.52^{n.s}$	$7.74^{n.s}$	33.85**	150.48*	480.43**
Nitrogen×Genotype	18	$81.14^{n.s}$	$3.72^{n.s}$	$541.55^{n.s}$	$0.51^{n.s}$	$21.97^{n.s}$	30.99**	$73.85^{n.s}$	242.59**
Iron× Genotype	9	$85.39^{n.s}$	$1.64^{n.s}$	1389.65**	$0.40^{n.s}$	$6.64^{n.s}$	32.56**	128.16*	356.18**
Nitrogen×Iron×Genotype	18	$65.18^{n.s}$	$2.60^{n.s}$	755.3**	$0.52^{n.s}$	$11.88^{n.s}$	25.63**	119.62*	336.75**
Residual (b)	78	154.64	3.12	329.5	0.94	18.94	2.66	5719.17	87.49
C.V (%)		22.88	24.6	29.94	31.19	13.25	21.9	31	32.39

PH: Plant height; HP: heads per plant; SH: seeds per head; BP: branches per plant; SW: 1000-seed, weight; SY: seed yield; BY: biological yield, HI: harvest index.

Table 2. Mean comparisons of nitrogen fertilizers for studied traits in safflower.

Nitrogen (N: kg/ha)	Means of the studied traits							
	PH	HP	SH	BP	SW	SY	BY	HI
N_1:50	54.46^a	7.14^a	63.15^a	3.7^a	18.65^a	5.48^c	23.09^a	24.87^b
N_2:100	56.63^a	7.49^a	67.39^a	2.99^a	18.65^a	9.08^a	32.52^a	31.37^a
N_3:150	51.89^a	6.91^a	62.14^a	3.27^a	18.65^a	7.54^b	33.96^a	30.41^a

PH: Plant height; HP: heads per plant; SH: seeds per head; BP: branches per plant; SW: 1000-seed weight; SY: seed yield; BY: biological yield; HI: harvest index; ¥: similar alphabets followed in a column denote they are statistically insignificant at P<0.01.

Table 3. Mean comparisons of Iron fertilizers for traits measured in safflower.

Fertilizer treatments	Means of the studies traits							
	PH	HP	SH	BP	SW	SY	BY	HI
F_1:sulphate of iron spraying with 1/1000 dose	53.60^a	7.08^a	57.13^a	3.06^a	32.83^a	6.08^b	24.87^a	27.56^a
F_2:sulphate of iron spraying with 2/1000 dose	55.02^a	7.27^a	64.69^a	3.16^a	32.86^a	8.08^a	23.91^a	30.25^a

PH: Plant height; HP: heads per plant; SH: seeds per head; BP: branches per plant; SW: 1000-seed weight; SY: seed yield; BY: biological yield; HI: harvest index; ¥: Similar alphabets followed in a column denote they are statistically insignificant at P<0.01.

The highest content of SY achieved from contemporary application of 100 kg/ha nitrogen and iron spraying with 2/1000 dose belonged to Shiraz landrace (Table 5). The lowest amounts of SY from contemporary application of 50 kg/ha nitrogen and iron spraying with 1/1000 dose belonged to 22-191 line (Table 5).

Correlation analysis

Correlation analysis has been studied in safflower (Khidir, 1984; Patil et al., 1990; Tuncturk and Ciftci, 2004; Omidi–Tabrizi, 2001). Seed yield showed a significant and positive correlation with seed SH and HI% (Table 6). There was a positive and significant correlation between SY and BY (r = 0.53) and SY with HI (r = 0.62) (Table 6).

Modeling of total seed yield based on linear multiple regression

In order to obtain a predictor model of yield variation and study the traits effective on yield, regression modeling was conducted based on stepwise regression, SH was considered as the main trait that explain 49% of the total seed yield variation. According to variance analysis, a highly significant regression model was obtained for this trait. It was one of the main yield components and it could

Table 4. Mean comparisons of genotypes for traits measured in safflower.

Genotype	Mean comparisons of studied traits			
	SH	SY	BY	HI
Golsefid	55.9ab	4.66e	25.28ab	18.51^{e}
22-191	54.77^{bc}	6.37^{cd}	23.18^{ab}	22.54^{de}
Goldasht	41.31^{c}	5.45^{de}	19.03^{b}	27.79^{b-e}
V-138	75.8^{a}	7.73^{bc}	27.42^{a}	34.03^{b-d}
Arak landrace	64.23^{ab}	9.58^{a}	25.61^{ab}	32.26^{ab}
Isfahan landrace	59.05^{b}	7.67^{bc}	25.69^{ab}	30.26^{a-c}
Isfahan14	53.77^{bc}	7.86^{b}	18.68^{a}	40.81^{a}
Isfahan 28	68.13^{ab}	7.94^{b}	27.45^{a}	23.9^{c-e}
Shiraz landrace	62.73^{ab}	6.88^{bc}	23.8^{ab}	25.78^{bc}
Kashan landrace	65.6^{ab}	9.67^{a}	24.71^{ab}	29.44^{a}

SH: Seeds per head; BP: branches per plant; SY: seed yield; BY: biological yield; HI: harvest index; ¥: similar alphabets followed in a column denote they are statistically insignificant at $P<0.01$.

Table 5. Interaction of nitrogen ×iron ×genotype on seed yield of safflower genotypes.

Nitrogen fertilizer (kg/ha)	Iron spraying (kg/1000 L H_2O)	Genotype	Seed yield
50	1/1000	22-191	1.17^{v}
50	1/1000	Goldasht	2.813^{t-v}
50	1/1000	138-V	7.23^{h-p}
50	1/1000	Arak landace	6.333^{j-r}
50	1/1000	Isfahan landrace	7.275^{h-p}
50	1/1000	Isfahan 14	7.872^{h-m}
50	1/1000	Isfahan 28	6.874^{i-q}
50	1/1000	Shiraz landrace	6.153^{k-s}
50	1/1000	Kashan landrace	5.549^{k-t}
50	1/1000	Golsefid	3.271^{r-v}
50	2/1000	22-191	1.536^{v}
50	2/1000	Goldasht	2.933^{s-v}
50	2/1000	138-V	3.902^{r-v}
50	2/1000	Arak landace	6.324^{j-r}
50	2/1000	Isfahan landrace	6.638^{i-q}
50	2/1000	Isfahan 14	1.944^{uv}
50	2/1000	Isfahan 28	6.808^{i-q}
50	2/1000	Shiraz landrace	5.804^{k-t}
50	2/1000	Kashan landrace	8.44^{g-l}
50	2/1000	Golsefid	3.183^{r-v}
100	1/1000	22-191	3.92^{p-v}
100	1/1000	Goldasht	1.637^{v}
100	1/1000	138-V	7.281^{h-p}
100	1/1000	Arak landace	2.815^{t-v}
100	1/1000	Isfahan landrace	6.392^{j-r}
100	1/1000	Isfahan 14	6.305^{j-r}
100	1/1000	Isfahan 28	5.229^{l-t}
100	1/1000	Shiraz landrace	5.568^{k-t}
100	1/1000	Kashan landrace	10.988^{e-g}
100	1/1000	Golsefid	7.247^{h-p}
100	2/1000	22-191	3.703^{q-v}
100	2/1000	Goldasht	6.293^{j-r}

Table 5. Contd.

100	2/1000	138-V	12.821[de]
100	2/1000	Arak landace	16.623[bc]
100	2/1000	Isfahan landrace	14.588[cd]
100	2/1000	Isfahan 14	9.637[f-i]
100	2/1000	Isfahan 28	10.286[e-h]
100	2/1000	Shiraz landrace	25.282[a]
100	2/1000	Kashan landrace	12.367[d-f]
100	2/1000	Golsefid	1.167[v]
150	1/1000	22-191	4.24[n-v]
150	1/1000	Goldasht	9.419[f-j]
150	1/1000	138-V	7.52[h-n]
150	1/1000	Arak landace	6.122[k-s]
150	1/1000	Isfahan landrace	7.405[h-o]
150	1/1000	Isfahan 14	13.147[de]
150	1/1000	Isfahan 28	3.916[p-v]
150	1/1000	Shiraz landrace	4.109[o-v]
150	1/1000	Kashan landrace	19.296[b]
150	1/1000	Golsefid	8.576[g-l]
150	2/1000	22-191	14.884[cd]
150	2/1000	Goldasht	6.759[i-q]
150	2/1000	138-V	4.965[m-u]
150	2/1000	Arak landace	8.682[g-k]
150	2/1000	Isfahan landrace	3.742[q-v]
150	2/1000	Isfahan 14	6.232[j-r]
150	2/1000	Isfahan 28	14.262[cd]
150	2/1000	Shiraz landrace	5.024[m-u]
150	2/1000	Kashan landrace	7.031[h-p]
150	2/1000	Golsefid	5.739[k-t]

Similar alphabets followed in a column denote they are statistically insignificant at P<0.01.

Table 6. Correlation coefficients between studied traits in safflower.

Coefficients	PH	HP	SH	BP	SY	BY	SW	HI
PH	1							
HP	0.22*	1						
SH	0.11	0.25*	1					
BP	-0.07	0.37**	0.15	1				
SY	0.03	0.02	0.48**	0.003	1			
BY	-0.04	0.15	0.59**	0.009	0.53**	1		
SW	-0.16	-0.05	-0.07	0.07	-0.03	-0.08	1	
HI	0.10	0.007	0.07	-0.02	0.62**	-0.21*	-0.05	1

*and ** are significant at P<0.05 and P<0.01, respectively. SH: Seeds per head, BP: branches per plant; SY: seed yield; BY: biological yield; HI: harvest index.

play the most important role in improvement of seed yield. Finally, the highest seed yield obtained from 100 kg/ha nitrogen and iron spraying with the dosage of 2/1000 and belonged to Shiraz landrace. In this research, Shiraz landrace and Golsefid had the most and the leastseed yield, respectively. Das and Ghosh (1993) examined the effects of four different doses of nitrogen on safflower and found that fertilizer doses significantly affected yield and its components at the 60 kg/ha dose as an optimum dose.

In another study, Cabi (1990) reported the significant effect of nitrogenous fertilizer forms on the safflower seed yields and found that the highest seed yield was obtained from ammonium nitrate with a dose of 120 kg N/ha^{-1} (Cabi, 1990). Application of 100 kg/ha and iron spraying with 2/1000 dose is known as the useful combination of nitrogen and iron rates for improvement of seed yield. Furthermore, the application of these ratios is recommendable for safflower improvement in this region. Seed number/head had significant and positive correlation with seed. In relation to seed yield, it is suggested that indirect selection for SH could lead to increase seed yield genotypes in safflower breeding programs.

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