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Effects of Nitrogen and Phosphorus Fertilizers on Safflower Yield in Dry Lands Condition

Akbar Haghighati Malek
Dry Lands Agricultural Research Institute (DARI),
PO Box 119, 5517643511 Maragheh, Iran
Email: a.haghighati@areo.ir

Farhad Ferri
Dry Lands Agricultural Research Institute
(Deputy, DARI), Kermanshah, Iran

***Abstract* –To determine the effects of different levels of nitrogen and phosphorus fertilizers on the seed yield of new safflower cultivars, a study was carried out at two different dryland research stations in Iran (Maragheh and Sararoud) for two years (2004-2005). The experiment compared four nitrogen fertilizer levels (0, 30, 60 and 90) kg.ha-1 and three phosphorus fertilizer levels (0, 30 and 60) kg.ha-1 in two safflower genotypes (V1, S-36 and V2, 79-299) in Maragheh and two safflower genotypes (V1, PI-37598 and V2, S-541) in Sararoud, in a factorial random complete block design with 3 replications. Nitrogen fertilizer was supplied as urea (45% N) and phosphorus fertilizer as triple super phosphate (46% P2O5). In each year, the crop was harvested after maturity and mean yield was analyzed statistically. In Maragheh, the results indicated that increasing nitrogen fertilizer increased seed and biomass yield whereas phosphorus fertilizer did not affect yield. In the interaction of variety with nitrogen and phosphorus fertilizers, application of 90 kg.ha-1 nitrogen and 60 kg.ha-1 phosphorus in 79-299 led to the highest seed yield (961 kg.ha-1) and treatment with 90 kg.ha-1 nitrogen and no phosphorus led to the highest biomass yield (4173 kg.ha-1). In Sararoud, increasing nitrogen fertilization did not increase seed yield but did increase plant height. In the interaction between nitrogen and phosphorus fertilizers, the use of 60 kg.ha-1 nitrogen and 30 kg.ha-1 phosphorus led to the highest seed yield (1283 kg.ha-1). Based on the amount of precipitation and yield in different years, we recommend the application of 90 kg.ha-1 nitrogen fertilizer together with 30 kg.ha-1 phosphorus in Maragheh regions, and 60 kg.ha-1 nitrogen fertilizer together with 30 kg.ha-1 phosphorus in Sararoud drylands for safflower production. We conclude that safflower seed yield differed depending on nitrogen fertilization in Maragheh. However, phosphorus fertilization did not increase safflower seed yield in Maragheh or Sararoud.**

***Keywords* – Nitrogen, Phosphorus, Safflower, Grain Yield, Dry Lands.**

I. Introduction

Safflower (*Carthamus tinctorius*) is an annual oilseed crop known as carthame or safran bâtard in French, cártamo or alazor in Spanish, cartamo or falso zafferano in Italian, and Saflor (among other names) in German (17). Seed oil content ranges from 30% to 40%. The thistle-like plants have a central branching stem with a variable number of branches and a tap-root system which is well adapted to drier areas. It produces an oil rich in polyunsaturated fatty acids, which play an important role in reducing blood cholesterol levels.

In Iran safflower used as a food and oil crop for humans and livestock, and also as a source of dye color extracted from its flowers for industrial applications. Recently, safflower has received attention as a source of crude oil, and for its potential to increase oil yields, especially as a dryland crop, with the development of suitable agricultural practices. However, the price of saffron oil is twice that of wheat germ oil, and little research has been done to investigate its potential (2,6). Safflower can be grown in dryland areas at altitudes ranging from below 1000 meters to 2300 meters above sea level. Although it can be planted at higher elevations, oil yields are decreased. Its thousand-kernel weight varies from 25 to 50 g in different areas, with a seed yield of 500 to 1200 kg.ha-1 (1,5). From an economic point of view safflower can compete with common crops such as wheat, barley, lentils and peas. Since safflower is more resistant to drought than other crops, it can be grown in strict drylands in rotation with wheat and barley as the main periodic replacement products (3,16).

Safflower is a winter-spring growing plant native to Asia and Africa, and is a member of the Sunflower family (Asteraceae). It is an erect, woody-stemmed branching plant with thistles, and is produced in large quantities throughout the USA, Mexico and India, and to a lesser extent in China and Africa, where it is used for human consumption and to make dye. Safflower requires deep soils with a neutral pH and prefers a medium soil texture. A waxy coating on its barbed leaves makes it highly drought tolerant (4,14). Its roots extend to a depth of up to 2.7 meters and can absorb and release nutrients from lower depths, another characteristic that makes this plant resistant to drought (12,15-17). Safflower has nutrient requirements similar to wheat, but compared to other annual plants, safflower has a longer growth period.

Safflower can also be grown in areas with little or no rainfall in the spring and summer. It has a wider planting window than other warm season crops, with good cold tolerance as a seedling and excellent drought tolerance as a mature plant. The deep root -system of safflower allows the plant to utilize nutrients that may not be available to small-grain crops. It is a long-season crop, so it extracts water from the soil for a longer period than cereal crops. The long taproot can draw moisture from deep within the subsoil(11). Safflower is a good rotation crop with small grains or on fallow because it helps to break weed and disease cycles. Safflower is normally grown in rotation with cereals, but can also be grown in rotation with legumes, pastures, fallows, oilseeds and cover crops.

Nitrogen deficiency reduces plant amino acid content – a basic element for the construction of amino acids and proteins (7,9-10). Phosphorus is a major component of genetic material in plants, and phosphorus deficiency decreases growth rate and seed yield (7,10). Purple pigments and dark green leaves can be a symptom of phosphorus deficiency (11). However, soil testing and appropriate fertilization, including field observations, are reliable ways to achieve optimal yields (18,19).

Although new safflower varieties have been introduced and adapted to cold regions and dryland areas, knowledge is lacking about optimal nitrogen and phosphorus fertilization regimes to increase safflower oil yields. The study reported here was designed to determine the effects of different regimes of nitrogen and phosphorus fertilization on the yield and oil content of safflower (*Carthamus tinctorius* cv. lines) grown in dryland soils. A further aim of this study was to provide farmers and extension workers with information they need to make safflower a viable alternate crop in agricultural prairieland regions. An additional aim was to seek ways to prevent the indiscriminate use of chemical fertilizers and support sustainable agriculture methods.

Vegetable oil consumption in Iran is 850,000 tons per year, but only 10 percent of the oil is produced domestically. Thus an important priority for the agricultural sector is to increase seed and oil yields of safflower. New safflower varieties adapted to dryland cultivation have been introduced in cold areas

II. Materials and Methods

To determine the effects of nitrogen and phosphorus fertilization on safflower cultivar oil yields in dryland farming, this experiment used a nitrogen fertilizer at 0, 30, 60 and 90 kg.ha-1 (N0, N30, N60, N90) and a phosphorus fertilizer at 0, 30 and 60 kg.ha-1 (P0, P30, P90). Two new safflower cultivars, S-36 (thorny safflower) and 79-299 (thorn-less safflower) were grown for 3 years in Maragheh. At the Sararoud location, two other new dryland cultivars (PI-537598 and S-541) were grown for two years in a factorial random complete block design experiment with 3 replications.

Nitrogen fertilizer was supplied as urea (45% N) and phosphorus fertilizer as triple super phosphate (46% P2O5). Plant height, seed yield and crude oil yield were recorded. Safflower seeds were disinfected with fungicide and then seeded at 30-cm row spacing in 2.5 × 6 m plots (15 m2) with an experimental seed drill (Winterstriger). Before planting, soil samples were sent to the laboratory for physical and chemical analysis (1,4). Plant phonological growth stages (germination, flowering and seed emergence) were recorded. At crop maturity the plots were harvested, the margins were discarded (discard width 150 cm) and the average seed yield was obtained and compared statistically.

III. Results

1. Dryland Agricultural Research Station at Maragheh

1.1. Soil analysis

To evaluate soil fertility before seeding, a 2-kg sample of 30 cm soil was obtained from the field at Maragheh sites and analyzed with Iranian Standard methods developed by the Soil and Water Research Institute (8).

Table 1: Results of soil analysis at the Maragheh experimental plot

Year	Total N (%)	Electrical conductivity (dS.m-2)	pH	Total neutralizing value (%)	Organic carbon (%)	P (ppm)	K (ppm)	Clay (%)	Silt (%)	Sand (%)
2003-2004	0.06	0.52	7.8	4.00	0.50	6.8	450	48	34	18
2004-2005	0.07	0.45	7.8	5.0	0.56	8.1	510	55	26	18
2005-2006	0.05	0.05	7.8	2.50	0.54	8.8	550	45	36	19

1.2. Crop yield in Maragheh: Combined 3-year analysis 2003-2004, 2004-2005 and 2005-2006)

The results from Maragheh show that different amounts of nitrogen fertilizer increased safflower seed and biomass yield. Compared to other elements, nitrogen is one of the main essential nutrients for safflower growth (Table 2 and Figure 1).

Analysis of variance showed significant differences between safflower lines. Nitrogen fertilization had a significant effect ($p<0.01$) on seed yield in all years, but phosphorus fertilizers had no significant effect on yield (Table 2). Seed yield and oil content increased with increasing doses of nitrogen fertilizer. In our test plots optimum yields were obtained with 60 kg.ha-1 nitrogen and 30 kg.ha-1 phosphorus. In contrast, increasing the rate of nitrogen fertilization to more than 60 kg.ha-1 increased only straw and stubble yield.

In the interaction between safflower cultivars and nitrogen or phosphorus fertilizers, treatment N90P60 in cultivar 79-299 led to the highest seed yield (961 kg.ha-1), and treatment N90P0 in the same cultivar led to the highest biomass yield (4173 kg.ha-1) (Table 2-6).

As Table 7 shows, different levels of nitrogen and phosphorus fertilization had no significant effect on dryland safflower production at the Sararoud site.

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Table 2: Three-year combined ANOVA for the effect of safflower varieties, nitrogen and phosphorus fertilizers on seed and biomass yield and plant height

Source of variation	**Degree of Freedom**	**Mean Squares**		
		Seed yield	**Biomass**	**Plant height**
Factor A (Year)	2	96386.55	52979248.9	2957.3
Error	9	392952.4	11684427.4	325.87
Factor C (Variety)	1	277928.6 **	3695483.29 **	404.23 **
AC	2	330503.6 **	3159013.16 **	386.51 **
Factor D (Nitrogen)	3	306229.6 **	6729009.69 **	117.22 **
AD	6	144241.7 **	3994604.45 **	114.93 **
CD	3	56625.11	235530.527	32.519
ACD	6	38752.05	196219.989	34.964
Factor E (Phosphorus)	2	46579.72	1002809.46	34.065
CE	2	26309.63	773839.385	103.33 *
ACE	8	19666.02	610855.367	4.561
DE	6	32650.71	440187.619	58.904
ADE	16	29938.07	870608.709 *	27.776
CDE	6	33731.16	223282.957	50.189
ACDE	8	72113.65 *	208781.197	49.698
Error	207	32480.02	527634.507	28.194
CV %		23.51	20.09	9.13

** Significant at $p<0.01$,* significant at $p<0.05$, ns not significant.

Table 3: Main effects of different safflower varieties on seed yield LSD 1% = 110.48 kg.ha-1

Variety	**Yield (kg.ha-1)**	**DMRT 1%**
(s-36)	735.3	B
(79-299)	797.5	A

Table 4: Main effects of nitrogen fertilization regimes on safflower seed yield
LSD 1% = 156.2 kg.ha-1

Nitrogen fertilization (kg.ha-1)	**Seed yield (kg.ha-1)**	**DMRT 1%**
N0	679.3	B
N30	769.5	AB
N60	779.6	AB
N90	837.1	A

Table 5: Main effects of nitrogen fertilization regimes on safflower biomass yield
LSD 1% = 629.5 kg.ha-1

Nitrogen fertilizer (kg.ha-1)	**Biomass yield (kg.ha-1)**	**DMRT 1%**
N0	3201.7	B
N30	3631.2	AB
N60	3692.8	AB
N90	3936.4	A

2. Sararoud Dryland Agricultural Research Station: combined 2-year analysis 2004-2005 and 2005-2006

Analysis of variance showed no significant differences between safflower lines and nitrogen fertilizer regimes in terms of seed or biomass yield. In contrast, phosphorus fertilizer levels had a significant effect on biomass yield (Table 6).

In the interaction between safflower cultivar and nitrogen or phosphorus fertilizers, treatment N90P30 in cultivar S-541 led to the highest seed yield (1284 kg.ha-1 (Table 6-10).

Table 6: Two-year combined analysis of variance for effects of safflower varieties, nitrogen and phosphorus fertilization on the seed yield and plant height

Source of Variation	D.F	Mean Squares	
		Seed yield (kg.ha-1)	Plant height (cm)
Factor A (Year)	1	367908.8 ns	560.667 ns
Error	2	30728.01	123.208
Factor C (Variety)	1	129874.6 ns	20.167 ns
AC	1	691391.8 **	104.167 ns
Factor D (Nitrogen)	3	84345.54 ns	181.861 **
AD	3	17002.29 ns	12.694 ns
CD	3	10350.93 ns	50.361 ns
ACD	3	15914.93 ns	19.528 ns
Factor E (Phosphorus)	2	28198.97 ns	12.469 ns
CE	2	6343.969 ns	24.51 ns

ACE	4	4006.865 ns	36.698 ns
DE	6	132354.2 *	21.08 ns
ADE	8	65198.55 ns	29.469 ns
CDE	6	41164.55 ns	17.122 ns
ACDE	4	319781.4 **	1.24 ns
Error	46	58876.18	31.621
CV %		22.57	7.50

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

Table 7: Main effects of safflower variety on seed yield
LSD 5% = 195.5 kg.ha-1

Variety	Yield (kg.ha-1)
(553798)	1112
(S-541)	1038

Table 8: Main effects of nitrogen fertilization regime on safflower seed yield
LSD 5% = 276.5 kg.ha-1

Nitrogen fertilization (kg.ha-1)	Seed yield (kg.ha-1)
N0	1062
N30	997
N60	1108
N90	1132

Table 9: Main effects of nitrogen fertilization regimes on safflower plant height
LSD 1% = 19.4 cm

Nitrogen fertilization (kg.ha-1)	Plant height (cm)
N0	71.8
N30	73.7
N60	78.04
N90	76.3

Table 10: Interaction effects between different safflower varieties and nitrogen and phosphorus fertilization on seed yield and plant height

Nitrogen and phosphorus regimes * Safflower variety	Seed yield (kg.ha-1)	Plant height (cm)
	LSD 5% = 677.4 kg.ha-1	LSD 5% = 4.47 cm
N0P0 V1	987.5	69
N0P30 V1	1043.5	71
N0P60 V1	1181.75	72.5
N30P0 V1	997	72
N30P30 V1	1087	73.5
N30P60 V1	1052.5	74.5
N60P0 V1	1340.5	79.75
N60P30 V1	1185	82.25
N60P60 V1	902.5	78.75
N90P0 V1	1223	77
N90P30 V1	1202.5	76.5
N90P60 V1	1141.25	78.75
N0P0 V2	1097	71.75
N0P30 V2	915.5	74
N0P60 V2	1147.5	72.75
N30P0 V2	865	72.75
N30P30 V2	1048.5	75.0
N30P60 V2	937	74.75
N60P0 V2	1226	79.75
N60P30 V2	1029.25	71.75
N60P60 V2	967.25	76.0
N90P0 V2	936.25	76.75
N90P30 V2	1284.75	71.75
N90P60 V2	1007.25	75.50

IV. Discussion

Nitrogen is the main soil-limiting factor in dryland agricultural production, since the amount of this nutrient is usually less than that required for maximum plant production. The results of this study confirm the result of most studies in dryland areas of the United States (7, 10), and confirm earlier findings in some arid regions in the Middle East (16). The pattern of biomass yield data (Table 6) was similar to that found for seed yield.

Table 2 shows that the effect of nitrogen fertilization differed significantly across different varieties of safflower in terms of seed and biomass production. The highest seed yield (961 kg seed.ha-1) and biomass yield (1941 kg biomass.ha-1) were obtained with the application of 90 kg N ha-1 in cultivar 79-299. These data suggest that treatment N90P60 is the most suitable fertilizer formula for safflower production in the dryland region we studied. These findings confirm earlier results in most other dryland areas, but contrast with the findings in some regions such as North Dakota in the United States (7). Maximum production (991 kg.ha-1) was observed with a nitrogen input of 90 kg.ha-1, which suggests that 11 kg of seed was produced per kilogram of nitrogen fertilizer. Safflower seed production per kilogram of fertilizer was reported as 20 kg in a Great Plains site in the United States, and 18 kg in India (13, 14).

In China and India, the largest producers of safflower in the world, fertilization with 50 kg.ha-1 nitrogen and 30 kg.ha-1 phosphorus has been recommended to obtain a yield of 1 ton of safflower seed (15). This is slightly less than the recommended amount based on the experiments reported here. In addition, the average safflower oil yield in these countries is 30% to 41%, and these values are greater than average amount of safflower oil (30% 33%) produced in dryland areas in Iran because of the use of appropriate cultivars and climate conditions (5, 13).

As shown in Figure 1, increasing the rate of nitrogen fertilization to more than 60 kg.ha-1 will increase only straw and stubble (biomass) production. This suggests that the application of more than 90 kg.ha-1 of nitrogen fertilizer in dry areas will not result in further increases in

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seed and oil production rates. This finding corroborates the recommendation for fertilization based on a study of safflower cropping in very dry areas of the United States (Colorado), where the average annual rainfall is less than 250 mm (13).

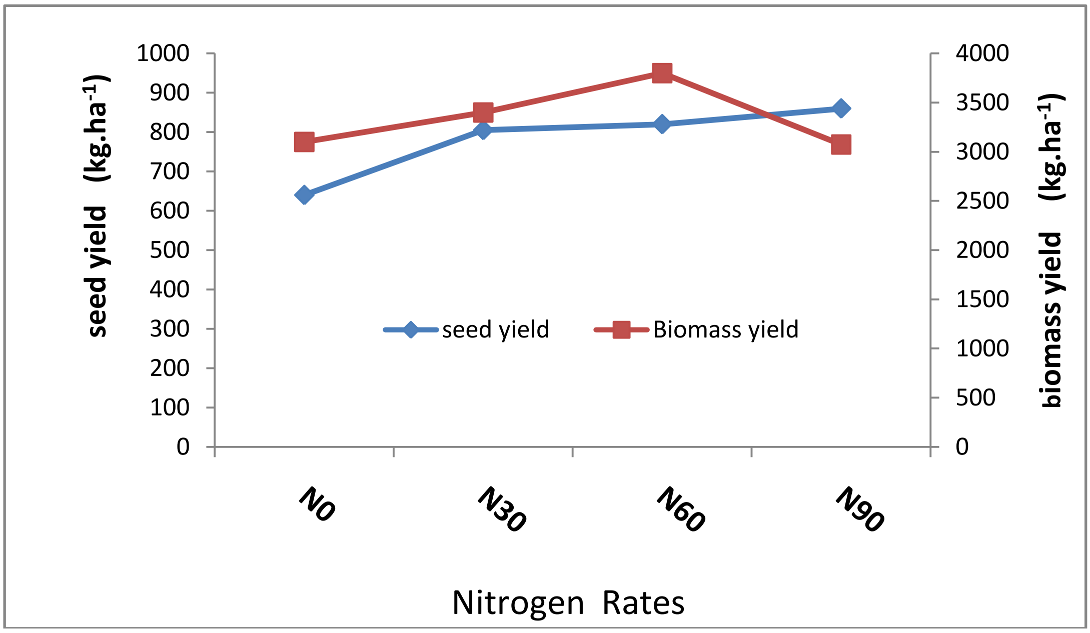

Fig.1. Effects of nitrogen fertilizers on grain and biomass yield in dryland safflower

Yield and oil content of the seed increased with increasing rates of nitrogen fertilization. Statistically significant optimum yields were obtained with the combination of 68 kg.ha-1 nitrogen and 40 kg.ha-1 phosphorus.

As shown in Table 6 different levels of fertilizers had no significant effect on dryland safflower seed yield in the Sararoud region. This result may reflect the low level and unsuitable distribution pattern of rainfall during the growing period in the region.

V. Conclusion

Considering the amount of rainfall and our findings for safflower seed and biomass production in different years, safflower production appears to be best enhanced by applying 90 kg.ha-1 nitrogen and 30 kg.ha-1 phosphorus in Maragheh dryland areas, and applying 60 kg.ha-1 nitrogen and 30 kg.ha-1 phosphorus in Sararoud dryland areas.

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