Research Journal of Agronomy 4 (3): 57-62, 2010
ISSN: 1815-9354


# Study on the Effects of Nitrogen and Phosphorus Fertilizers on the Yield and Oil Content of Safflower Lines in Drylands

Akbar Haghighati
Dry Lands Agricultural Research Institute (Dari), P.O. Box: 119,
P. C. 5517647885, Maragheh, Iran

**Abstract:** In order to determine the effects of different levels of nitrogen and phosphorus fertilizers on the yield and oil content of new safflower genotypes a study carried out in 2 different dryland research stations of Iran (Maragheh and Sararoud) for 2 years (2004-2005). The experiment was arranged with 4 nitrogen fertilizer levels 0, 30, 60, 90 kg ha$^{-1}$ and 3 phosphorus fertilizer levels 0, 30, 60 kg ha$^{-1}$ with tow safflower genotypes (V1 = No36 and V2 = 79-299) in Maragheh and (V1 = 537598 and V2 = S-541) in Sararoud as factorial RCBD with 3 replications. Nitrogen fertilizer was supplied as urea (45% N) and phosphorus fertilizer as triple super phosphate (46% $P_2O_5$). In each year, the crop harvested after maturity and mean yield analyzed statistically. In Maragheh, the results indicated that increasing nitrogen fertilizer increased the grain and biomass yield but phosphorus fertilizer did not affect the yield. In the interaction effect of variety with nitrogen and phosphorus fertilizers, application of V2N90P60 had the highest seed yield (961 kg ha$^{-1}$) and treatment V2N90P0 had the highest biomass yield (4173 kg ha$^{-1}$). In Sararoud, increasing nitrogen fertilizer did not increase seed yield but it increased plant height. In nitrogen and phosphorus fertilizers interaction, application of N60P30 had the highest seed yield (1283 kg ha$^{-1}$). Regarding the amount of precipitation and yield in different years, application of 90 kg ha$^{-1}$ nitrogen fertilizer together with 30 kg ha$^{-1}$ phosphorus (N90P30) is recommended in Maragheh regions and application of 60 kg ha$^{-1}$ nitrogen fertilizer together with 30 kg ha$^{-1}$ phosphorus (N60P30) is recommended in Sararoud drylands for safflower production. It can be concluded that safflower grain yield differed at different levels of nitrogen fertilizer in Maragheh regions. However, phosphorus fertilizer did not increase safflower grain yield in Maragheh and Sararoud.

**Key words:** Nitrogen, phosphorus, safflower, oil content, drylands, Maragheh

## INTRODUCTION

Oil consumption in the country annually is 850,000 ton but only 10% of it is being provided by domestic production. Regarding the importance of oil seeds, increasing grain and oil yield of safflower is one of important priorities of agriculture sector. New safflower varieties that has introduced in cold areas have good adaptability with dryland.

Safflower crop with the scientific name, Carthamus tinctorius called safflower in English language and safran and batard in French language, Carthame in Spanish and Cartamo in Italian language and Saflor in German language (Lajevardi, 1980). It is an annual oil seed crop (seed-oil content ranges from 30-40%) and a thistle like plant with a central branch stem a varying number of branches and a tap-root system which is well adapted to drier areas. It produces an oil rich in poly-unsaturated fatty acids which plays an important role in reducing blood cholesterol levels. In Iran, safflower used as food and oil crop for human and livestock and also dye color extracted from its flowers has industrial applications. Recently, safflower is considered as one of the crude oil supply plants, hope that its extension through development of agriculture can increase oil yield in the country especially in dryland areas. Although, its price is twice of wheat grain but few researches has been done on it (Dahnke *et al*., 1992). Safflower can be grown on the dryland areas of the country on lands with <1000-2300 m altitude whereas, it can be planted in higher elevations but the amount of it's oil will be decreased.

Depending on the different regions its TKW varies from 25-50 g with 500-1200 kg ha$^{-1}$ grain yield (Abdolrahmani, 2009; Croissant *et al*., 1986). From economic point of view safflower can compete with common crops such as wheat, barley, lentils and peas. Since safflower is highly resistant to drought than other crops therefore, it can be grown in strict drylands in rotation by wheat and barley along main periodic replacement products (Auld *et al*., 1981; Oelke *et al*., 1992). Safflower is a winter-spring growing plant native to Asia and Africa and in the same family as Sunflower. 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 China and Africa where it is used for human consumption and to make dye. Safflower requires deep soils with and neutral pH and prefer medium soil texture. Wax coating materials on it's leaves and especially having barbed leaves, makes it highly drought tolerant (Kubsad *et al*., 1999; Lyon *et al*., 1998). Safflower has a similar, nutrient requirement to wheat and can access nutrients from lower depths. Compared with other annual plants, safflower has longer growth period and very deep and extended root up to depth of 2.7 m to absorb and release nutrients from the lower depths will help it in resistant to drought (Kubsad *et al*., 1999; Lyon *et al*., 1998; Mohammadi, 2001; Oelke *et al*., 1992). Safflower can also be grown in areas with little or no rainfall over spring and summer.

It has a wider planting window than the other warm season crops with good cold tolerance as a seedling and excellent drought tolerance as a mature plant. Safflower has a deep root system allowing the plant to utilise 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 tap-root can draw moisture from deep in the subsoil. Safflower is normally grown in rotation with cereals but can also be grown in rotation with legumes, pastures, fallows, oil seeds and cover crops. Nitrogen in combination with oxygen, hydrogen, carbon and sulfur produce amino acids. 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). Phosphorus also participates in making plants genetic constructions and its deficiency decreases growth rate and grain yield production (Berglund *et al*., 1998; Herdrich, 2001). Purple pigments and dark green leaves can be the symptom of phosphorus deficiency (Khademi *et al*., 2000). However, soil testing and fertilizer recommendations, including field observations are most reliable ways is to achieve optimal performance (Singh and Singh, 1980).

New safflower varieties were introduced in the cold regions of dryland areas with good adaptation and we are trying to determine the optimum nitrogen and phosphorus fertilizer rates that may increase safflower oil yield. Increasing dryland safflower grain and oil yield and prevention of the indiscriminate use of chemical fertilizers with the goal of sustainable agriculture can be achievements of this experiment.

## MATERIALS AND METHODS

In order to determine the effects of nitrogen and phosphorus fertilizers on the advanced safflower cultivars oil yield in dryland, this study carried out using 0, 30, 60 and 90 kg $ha^{-1}$ nitrogen fertilizers and phosphorus 0, 30 and 60 kg $ha^{-1}$ by tow new safflower cultivars (6 stickled safflower -36 and safflower No. V2-299-79 non-stickled) for 3 years and in Sararoud with new dryland cultivars of safflower V1 = 537598 and V2 = S-541 for 2 years in the form of factorial RCBD experiment with 4 replications.

Nitrogen fertilizer was supplied as urea (45% N) and phosphorus fertilizer as triple super phosphate (46% $P_2O_5$). The plant height the seed yield and the crude oil yield were investigated.

Safflower planted in 30 cm row spacing in 2.5×6 m (15 $m^2$) plots by experimental seed drill (winter striger). Seeds disinfected with fungicide before planting. Before planting the experiment, soil sampled and sent to the laboratory for physical and chemical analysis (Abdolrahmani, 2009; Bergman *et al*., 1979). Observations for the plant phonological growth stages such as germination, flowering and seed emergence has recorded down.

At the time of crop maturity, plots harvested after the elimination of margins and the average yield analyzed and compared statistically. Annual report and final report presented as final results. The objective of this study carried out in Maragheh and Sararoud dryland research stations of Iran in 2004 and 2005 was to determine the effects of different nitrogen and phosphorus fertilizers doses on the yield and oil content of safflower (Carthamus tinctorius cv.) lines in drylands and to give farmers and extension workers the information they need to make safflower a viable alternate crop in the regional prairies.

## RESULTS AND DISCUSSION

**Dryland agricultural research station of maragheh soil analysis:** To evaluate the general fertile soil before treatments a soil sample from each replicate consisting of 30-0 cm soil prepared and sent to the laboratory and analyzed based on the common methods of soil and water research institute and analyzed for physical and chemical characteristics. All soil analysis factors measured before implementation is shown in Table 1.

**Results of crop yield in Maragheh**

**Combined analysis of 3 years (2003-2006):** Analysis of variance showed that there was significant difference between safflower lines and the nitrogenous fertilizer had a significant effect ($p<0.01$) on the seed yield in all years but phosphorus fertilizers had no significant effect on the yield (Table 2-5). In the interaction of safflower cultivars and nitrogen and phosphorus fertilizers, the treatment of V2N90P60 had highest grain

Table 1: Results of soil analysis in the experiment place of Maragheh

| Years | Total N (%) | EC (ds. $m^{-2}$) | pH | T.N.V (%) | O.C (%) | P (ppm) | K (ppm) | Clay (%) | Silt (%) | Sand (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 2003-2004 | 0.06 | 0.52 | 7.8 | 4.0 | 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 | 2.5 | 0.54 | 8.8 | 550 | 45 | 36 | 19 |

Table 2: Three year combined ANOVA for effects of safflower varieties, nitrogen and phosphorus fertilizers on grain and biomass yield, plant height

| | | MS | | |
|---|---|---|---|---|
| S.O.V | DF | Grain yield | Biomass | Plant height |
| Factor A (year) | 2 | 96386.55 | 52979248.900 | 2957.300 |
| Error | 9 | 392952.40 | 11684427.400 | 0325.870 |
| Factor C (variety) | 1 | 277928.60** | 3695483.290** | 404.230** |
| AC | 2 | 330503.60** | 3159013.160** | 386.510** |
| Factor D (nitrogen) | 3 | 306229.60** | 6729009.690** | 117.220** |
| AD | 6 | 144241.70** | 3994604.450** | 114.930** |
| CD | 3 | 56625.11 | 235530.527 | 32.519 |
| ACD | 6 | 38752.05 | 196219.989 | 34.964 |
| Factor E (phosphorus) | 2 | 46579.72 | 1002809.460 | 34.065 |
| CE | 2 | 26309.63 | 773839.385 | 103.330* |
| 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 | 20.090 | 9.130 |

Significant in ($p<0.01$), *Significant in ($p<0.05$) and ns non-significant

Table 3: Main effects of different safflower varieties on grain yield LDS (1%) = 110.48 kg $ha^{-1}$

| Varieties | Yield (kg $ha^{-1}$) | DMRT (1%) |
|---|---|---|
| V1(39) | 735.3 | B |
| V2(79-299) | 797.5 | A |

Table 4: Main effects of nitrogen fertilizer rates on grain yield of safflower LSD (1%) = 156.2 kg $ha^{-1}$

| Nitrogen fertilizer (kg $ha^{-1}$) | Grain yield (kg $ha^{-1}$) | DMRT (1%) |
|---|---|---|
| N 0 | 679.3 | B |
| N 30 | 769.5 | AB |
| N 60 | 779.6 | AB |
| N 90 | 837.1 | A |

Table 5: Main effects of nitrogen fertilizer rates on biomass yield of safflower LSD (1%) = 629.5 kg $ha^{-1}$

| Nitrogen fertilizer (kg $ha^{-1}$) | Biomass yield (kg $ha^{-1}$) | DMRT (1%) |
|---|---|---|
| N 0 | 3201.7 | B |
| N 30 | 3631.2 | AB |
| N 60 | 3692.8 | AB |
| N 90 | 3936.4 | A |

yield 961 kg $ha^{-1}$ and the treatment of V2N90P0 had highest biomass yield (4173 kg $ha^{-1}$) (Table 6).

**Results of dryland agricultural research station of Sararoud**

**Combined analysis of 2 years (2004-2006):** Analysis of variance showed that there was not significant difference between safflower lines and nitrogen and levels in terms of grain and biomass yield but phosphorus fertilizers levels had significant effect on biomass yield (Table 7-10).

In the interaction of safflower cultivar and nitrogen and phosphorus fertilizers the treatments of V2N90P30 had highest grain yield (1284 1 Kg $ha^{-1}$ (Table 11). Safflower is a winter-spring growing plant. It can also be grown in areas with little or no rainfall over spring and summer. Since, safflower has a similar nutrient requirement to wheat.

It is normally grown in rotation with cereals but can also be grown in rotation with legumes, pastures, fallows, oilseeds and cover crops. Safflower can also be grown in areas with little or no rainfall over spring and summer.

Statistical analysis of Maragheh region shows that the effect of different amounts of nitrogen fertilizers increased grain and biomass yield of safflower, this means that compared with other elements, nitrogen is one of the main essential nutrients for the safflower growth (Table 2, Fig. 1).

It can be said that nitrogen is the main soil limiting factor in dryland agricultural production since it is usually less than the required amount to produce maximum plant product. The results of this study confirm the result of most dryland areas of the United States (Berglund *et al*., 1998; Herdrich, 2001) and also confirm findings in some arid regions of middle East (Oelke *et al*., 1992).

The straw yield data (Table 6) showed similar pattern recorded for grain yield. Also, Table 2 shows that the nitrogen fertilizer and varieties of safflower are significantly different in grain and biomass production while the highest seed yield (961 kg seed $ha^{-1}$) and (1941 kg biomass $ha^{-1}$) were obtained from the

Table 6: Interaction effects of different safflower varieties, nitrogen and phosphorus fertilizers on grain and biomass yield

| Nitrogen and phosphorus *varieties | Grain yield (kg ha$^{-1}$) LSD (5%) = 290.1 kg ha$^{-1}$ | Grain yield DMRT (5%) | (Biomass yield (kg ha$^{-1}$) LSD (5%) = 1169 kg ha$^{-1}$ | Biomass yield DMRT (5%) |
|---|---|---|---|---|
| N0POV1 | 658.0 | BC | 3014 | A |
| N0P30V1 | 684.1 | ABC | 3092 | A |
| N0P60V1 | 697.6 | ABC | 3411 | A |
| N30P0V1 | 726.7 | ABC | 3474 | A |
| N30P30V1 | 699.5 | ABC | 3296 | A |
| N30P60V1 | 774.9 | ABC | 3718 | A |
| N60P0V1 | 755.5 | ABC | 3482 | A |
| N60P30V1 | 655.6 | BC | 3178 | A |
| N60P60V1 | 860.9 | ABC | 3945 | A |
| N90P0V1 | 785.8 | ABC | 3921 | A |
| N90P30V1 | 756.3 | ABC | 3745 | A |
| N90P60V1 | 769.6 | ABC | 3751 | A |
| N0POV2 | 631.6 | C | 3004 | A |
| N0P30V2 | 753.9 | ABC | 3399 | A |
| N0P60V2 | 651.1 | BC | 3291 | A |
| N30P0V2 | 828.0 | ABC | 3834 | A |
| N30P30V2 | 782.7 | ABC | 3639 | A |
| N30P60V2 | 805.8 | ABC | 3827 | A |
| N60P0V2 | 800.3 | ABC | 3804 | A |
| N60P30V2 | 810.3 | ABC | 3904 | A |
| N60P60V2 | 795.4 | ABC | 3844 | A |
| N90P0V2 | 926.9 | AB | 4173 | A |
| N90P30V2 | 823.1 | ABC | 3985 | A |
| N90P60V2 | 961.1 | A | 4042 | A |

Table 7: Tow year combined analysis of variance for effects of safflower varieties, nitrogen and phosphorus fertilizers on the grain yield and plant height

| S.O.V | DF | Ms Grain yield (kg ha$^{-1}$) | Ms Plant height (cm) |
|---|---|---|---|
| Factor A (year) | 1 | 367908.8000$^{NS}$ | 560.667$^{NS}$ |
| Error | 2 | 30728.0101 | 123.208 |
| Factor C (variety) | 1 | 129874.6000$^{NS}$ | 20.167$^{NS}$ |
| AC | 1 | 691391.8000** | 104.167$^{NS}$ |
| Factor D (nitrogen) | 3 | 84345.5400$^{NS}$ | 181.861** |
| AD | 3 | 17002.2900$^{NS}$ | 12.694$^{NS}$ |
| CD | 3 | 10350.9300$^{NS}$ | 50.361$^{NS}$ |
| ACD | 3 | 15914.9300$^{NS}$ | 19.528$^{NS}$ |
| Factor E (phosphorus) | 2 | 28198.9700$^{NS}$ | 12.469$^{NS}$ |
| CE | 2 | 6343.9690$^{NS}$ | 24.510$^{NS}$ |
| ACE | 4 | 4006.8650$^{NS}$ | 36.698$^{NS}$ |
| DE | 6 | 132354.2000* | 21.080$^{NS}$ |
| ADE | 8 | 65198.5500$^{NS}$ | 29.469$^{NS}$ |
| CDE | 6 | 41164.5500$^{NS}$ | 17.122$^{NS}$ |
| ACDE | 4 | 319781.4000** | 1.240$^{NS}$ |
| Error | 46 | 58876.1800 | 31.621 |
| CV % | - | 22.5700 | 7.500 |

Significant in (p<0.01), *Significant in (p<0.05) and $^{NS}$ = Non-Significant

Table 8: Main effects of different safflower varieties on grain yield LDS (5%) = 195.5 kg ha$^{-1}$

| Variety | Yield (kg ha$^{-1}$) |
|---|---|
| V1 (553798) | 1112 |
| V2 (S-541) | 1038 |

Table 9: Main effects of nitrogen fertilizer rates on grain yield of safflower LSD (5%) = 276.5 kg ha$^{-1}$

| Nitrogen fertilizer (kg ha$^{-1}$) | Grain yield (kg ha$^{-1}$) |
|---|---|
| N 0 | 1062 |
| N 30 | 997 |
| N 60 | 1108 |
| N 90 | 1132 |

Table 10: Main effects of nitrogen fertilizer rates on plant height LSD 1% = 19.4 cm

| Nitrogen fertilizer (kg ha$^{-1}$) | Plant height (cm) |
|---|---|
| N 0 | 71.80 |
| N 30 | 73.70 |
| N 60 | 78.04 |
| N 90 | 76.30 |

Table 11: Interaction effects of different safflower varieties, nitrogen and phosphorus fertilizers on grain and plant height

| Nitrogen and phosphorus *safflower varieties | Grain yield (kg ha$^{-1}$) (LSD (5%) = 677.4 kg ha$^{-1}$) | Plant height (cm) (LSD (5%) = 4.47 cm) |
|---|---|---|
| N0POV1 | 987.50 | 69.00 |
| N0P30V1 | 1043.50 | 71.00 |
| N0P60V1 | 1181.75 | 72.50 |
| N30P0V1 | 9970.00 | 72.00 |
| N30P30V1 | 1087.00 | 73.50 |
| N30P60V1 | 1052.50 | 74.50 |
| N60P0V1 | 1340.50 | 79.75 |
| N60P30V1 | 1185.00 | 82.25 |
| N60P60V1 | 0902.50 | 78.75 |
| N90P0V1 | 1223.00 | 77.00 |
| N90P30V1 | 1202.50 | 76.50 |
| N90P60V1 | 1141.25 | 78.75 |
| N0POV2 | 1097.00 | 71.75 |
| N0P30V2 | 915.50 | 74.00 |
| N0P60V2 | 1147.50 | 72.75 |
| N30P0V2 | 0865.00 | 72.75 |
| N30P30V2 | 1048.50 | 75.00 |
| N30P60V2 | 0937.00 | 74.75 |
| N60P0V2 | 1226.00 | 79.75 |
| N60P30V2 | 1029.25 | 71.75 |
| N60P60V2 | 967.25 | 76.00 |
| N90P0V2 | 936.25 | 76.75 |
| N90P30V2 | 1284.75 | 71.75 |
| N90P60V2 | 1007.25 | 75.50 |

application of the 90 kg N ha$^{-1}$ in V2 so that the treatment V2N90P60 is the most suitable fertilizer formula for safflower production in this dryland region. These findings confirm research results suggested by the

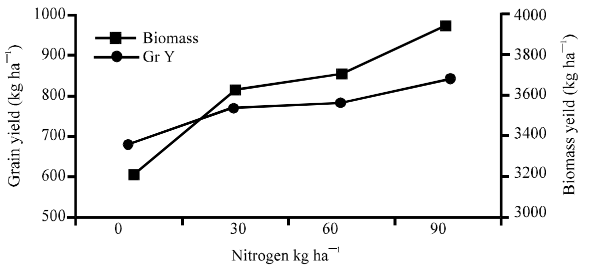


Fig. 1: Effects of nitrogen fertilizers on grain and biomass yield in dryland safflower

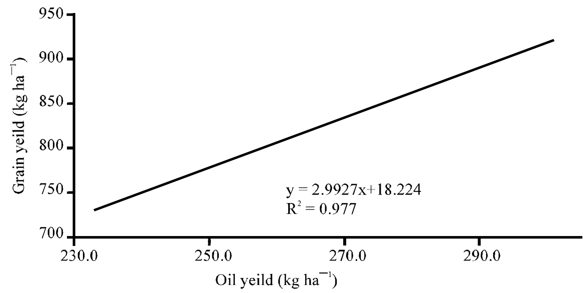


Fig. 2: Regression of grain yield and grain's oil yield in dryland safflower

most drylands research but is different from the results of some regions such as North Dakota in the United States. With the maximum production 991 kg ha$^{-1}$ safflower nitrogen input was 90 kg ha$^{-1}$ this means that each kg of nitrogen needed to produce 11 kg of grain. Whereas in (Great plain) of the United States it was 20 kg and the rate in India was18 kg of grain (Leshem *et al.*, 2000; Lyon *et al.*, 1998). In China and India, the highest safflower producers of in the world to produce 1ton safflower grain recommended applying 50 kg ha$^{-1}$ nitrogen and 30 kg ha$^{-1}$ phosphorus. Which is slightly less than the recommended amount of this experiment and it seems wisely because of its low efficiency of fertilizer consumption in Iran.

In addition, the average amount of safflower oil in these countries is 30-41% and that is more than average amount of safflower oil (30-33%) produced in dryland areas of the country because of its use of appropriate cultivars and climate conditions (Croissant *et al.*, 1986; Leshem *et al.*, 2000).

Safflower is a deep-rooted, long-season crop that with stands periods of drought longer than other annuals. It is particularly suited to dryland conditions. Safflower is a good rotation crop with small grains or on fallow in that it helps to break weed and disease cycles.

As it can be observed in Fig 2, grain yield production has high correlation with oil production, it means that if grain yield increases the oil production rate will increase linearly.

But increasing the rate of nitrogen, >60 kg ha$^{-1}$ will increase just straw and stubble, this means that application of >90 kg ha$^{-1}$ nitrogen fertilizer in dry areas will not increase grain and oil production rate. This results confirm the fertilizer recommendation in very dry areas of the United States (Colorado) for safflower cropping where the average annual rainfall is <250 mm (Leshem *et al.*, 2000).

Yield and oil content of the seed increased with increasing fertilizer N rates. Statistically significant optimum yields were obtained when the sum of 68 kg ha$^{-1}$ nitrogen and 40 kg ha$^{-1}$ phosphorus fertilizers were used.

As Table 7 shows that different levels of nitrogen and phosphorus fertilizers had not significant effect in dryland safflower in Sararoud region which can be the reason of low and improper distribution of rainfall in the region.

## CONCLUSION

As mentioned before, safflower has longer growth period and very deep and developed root system to absorb nutrients from the deep ground and release in top soil to help water absorption and increased fertilizer efficiency in drylands. Therefore, it is very drought resistant crop compared with other annual plants (Lyon *et al.*, 1998). Regarding the amount of rainfall and safflower grain and biomass production in different years, for Safflower production applying of 90 kg ha$^{-1}$ nitrogen and 30 kg ha$^{-1}$ phosphorus fertilizers (N90P30) in Maragheh dryland areas and applying of 60 kg ha$^{-1}$ nitrogen and 30 kg ha$^{-1}$ phosphorus fertilizers (N60P30) in Sararoud dryland areas can be recommended.

## REFERENCES

Abdolrahmani, B., 2009. Evaluation of safflower cultivars in Drylands. Final Report, Drylands Agricultural Research Institute. Maragheh, Iran. Reg. No. 733.

Auld, D.L., G.A. Murray, J.A. Benson, E.F. Mink, B.W. Studer and C.G. VanSlyke, 1981. Safflower, A Potential Crop for Northern Idaho. University of Idaho Cooperative Extension Service, USA.

Berglund, D.R., N. Riveland and J. Bergman, 1998. Safflower Production. NDSU Extension Service Publication, Dakota, USA.

Bergman, J.W., G.P. Hartman, A.L. Black, P.L. Brown and N.R. Riveland, 1979. Safflower production guidelines. Montana Agricultural Experiment Station, Capsule Info. Series, No. 8 (revised). Bozeman, MT USA., pp: 25.

Croissant, R.L., D.L. Johnson and J.F. Shanahan, 1986. Safflower Production in Colorado. Colorado State University Cooperative Extension, USA.

Dahnke, W.C., C. Fanning and A. Cattanach, 1992. Fertilizing Safflower. Soil Testing and Soil Science. Nebraska Cooperative Extension, USA.

Herdrich, N., 2001. Safflower Production Tips. Washington State University Cooperative Extension, USA., pp: 16.

Khademi, Z., M.J. Malakouti, H. Rezaee and P.M. Milani, 2000. Canola Optimal Nutrition. Agricultural Education Publications, Tehran, Iran.

Kubsad, V.S., C.P. Mallapur and C.P. Mansur, 1999. Contribution of production factors on yield of safflower under dryland conditions. Agricultural Research Station, Annigeri, India.

Lajevardi, N.S., 1980. Oil Seeds. Tehran University Publications, Tehran, Iran.

Leshem, Y., I. Bruckental, G. Ashbel, Z. Weinberg and Y. Landau, 2000. Safflower: A new crop for cattle feeding. Zichron Yaakov, February 7-9, pp: 101.

Lyon, D.J., D. David, R.S. Baltensperger and K. Eric, 1998. Growing Safflower in Nebraska. National Department of Agriculture, USA.

Mohammadi, M., 2001. Study on the effects of row spacing on seed yield of safflower in dryland conditions. Final Report, Gachsaran Agricultural Research Centre, Gachsaran, Iran.

Oelke, E.A., E.S. Oplinger, T.M. Teynor, D.H. Putnam and J.D. Doll *et al*., 1992. Safflower. Minnesota Extension Service and University of Minnesota, USA.

Singh, U.B. and R.M. Singh, 1980. Effect of graded levels of moisture regimes, N and P fertilization on seed yield, oil content and NPK uptake by safflower. Indian J. Agron., 25: 9-17.