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*Full Length Research Paper*

# Effect of micronutrients foliar application on yield and seed oil content of safflower (*Carthamus tinctorius*)

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**In order to investigate the effects of micronutrient foliar application on quantitative traits and seed oil content of safflower, a field experiment was carried out in 2008 to 2009 growing season at Research Farm of Faculty of Agriculture, Zabol University, Iran. The experiment was done using randomized complete block design with three replications. The experiment treatments included of: F1: control, F2: Fe, F3: Zn, F4: B, F5: Mn, F6: Fe+B, F7: Fe+Mn, F8: Fe+Zn and F9: Zn+B. These micronutrient fertilizers were used in two times as: 60 days after planting and 80 days after planting. The results revealed that micronutrients foliar application had a significant effect on seed and biological yield, 1000-seed weight and seed oil percentage; but the harvest index and number of seed per head was not significantly influenced by applied treatments. The maximum seed yield and biological yield as well as 1000-seed weight obtained from F2 treatment and the maximum oil percentage was achieved from F6. Also, maximum number of seed per capitol was obtained from F3. Overall, we concluded that micronutrient had positive effects on quantitative and qualitative traits of safflower in conditions of studied area.**

**Key words:** Micronutrient foliar application, yield, oil content, safflower.

## INTRODUCTION

Safflower (*Carthamus tinctorius* L.) is an important oilseed crop of the family compositae originated in southern Asia and is known to have been cultivated in China, India, Egypt and Iran (Ashri and Knowles, 1960). The oil content of safflower seed ranged between 35 to 50% that consists of about 90% unsaturated fatty acids, placing it as one of the best oils for popular consumption (Rahamatalla et al., 2001; Tahmasebpour et al., 2011). This crop adapted to relatively low rainfall areas receiving winter and spring rainfall with a low humidity during flowering and maturation (Knowles, 1976). One of the most important issues about increase of crop yield and improving the quality of agricultural products is balanced plant nutrition. Application of chemical fertilizers in Iran is very high and often more than crop needs (Malakouti and Tehrani, 1999). Foliar application of nutrients has become an efficient way to increase yield and quality of crops (Romemheld and El-Fouly, 1999; Savithri et al., 1999). Furthermore, this method can improve nutrient utilization and reduced environmental pollution by reducing the need of chemical fertilizers application in soils (Abou El-Nour, 2002). In addition to their advantages for crop production, they have a beneficial effect on human and livestock health (Malakouti and Tehrani, 1999; Sharma et al., 1992).

In arid and semiarid regions such as Iran, foliar application of nutrients is a more suitable option compared with soil fertilization when the roots can not provide necessary nutrients. Other advantages are quick compensation of nutrient deficiency and application of lesser rates and thus, reducing toxicity arises from excessive accumulation of elements and preventing nutrients fixation in the soil (Malakouti and Tehrani, 1999). Several researches indicated a positive influence of micronutrient application in increase of yield and quantitative parameters of crops (Tavassoli et al., 2010; Nagaraj, 1987; Mosavi et al., 2007; Paygozar et al., 2009). Foliar application of micronutrients (iron and zinc)

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**Table 1.** Chemical analysis of soil experiment.

| Mn ($mg.L^{-1}$) | Zn ($mg.L^{-1}$) | Fe ($mg.L^{-1}$) | Ca ($meq.L^{-1}$) | P ($meq.L^{-1}$) | K ($meq.L^{-1}$) | N ($meq.L^{-1}$) | EC ($dS.m^{-1}$) | pH |
|---|---|---|---|---|---|---|---|---|
| 0.32 | 1.61 | 0.03 | 12.1 | 1.56 | 317 | 0.03 | 1.8 | 8.3 |

**Table 2.** Analysis of variance for measured traits of safflower.

| SOV | df | Leaf chlorophyll | Seed no. | 1000-seed weight | Seed yield | Biological yield | Harvest index | Oil content |
|---|---|---|---|---|---|---|---|---|
| | | Mean square | | | | | | |
| Replication | 2 | $278.7^{ns}$ | $52.9^{ns}$ | $19.2^{ns}$ | $22591.5^{ns}$ | $187045^{ns}$ | $3.42^{ns}$ | $1.28^{ns}$ |
| Treatment | 8 | $516.5^{ns}$ | $7.28^{ns}$ | 28.2* | 105994.2* | 1222280* | $4.10^{ns}$ | 2.26* |
| Error | 16 | 755.7 | 7.81 | 9.06 | 31216.2 | 425233 | 23.0 | 5.55 |
| CV (%) | - | 17.74 | 10.36 | 8.01 | 17.41 | 15.94 | 19.21 | 10.70 |

*, **: Significantly different at 5 and 1% levels of probability, respectively; Ns: non-significant.

in growth various stages of sunflower had significant positive effect on 1000-seed weight, plant height, biological yield, grain yield, harvest index and oil content (Babaeian et al., 2011). Research results of Rashid et al. (1994) and Prasad and Prasad (1994) reported that with foliar spraying of copper and zinc, the yield of rapeseed and oil and protein content of the seeds increased significantly. Movahedi-Dehnavi et al. (2009) and Lewis and McFarlane (1986) reported that in micronutrients deficiency condition, use of micronutrients on shoots lead to increasing quantity and quality of safflower. Sangale et al. (1981) reported that safflower plants sprayed with B, Fe, Zn and a combination of B+Zn showed significant increment of grain yield, and among these treatments the most seed yield was achieved from spraying with B micronutrient.

Lewis and McFarlane (1986) indicated that manganese significantly increased seed yield of safflower through the increase of number of seeds per plant. Babhulkar et al. (2000) stated that foliar and soil application of zinc and sulfur along with nitrogen and phosphorus fertilizers significantly increased grain yield, protein and oil content of safflower. The objective of this study was to investigate the effects of foliar application of micronutrients individually or in combination on the growth, yield and seed oil content of safflower plants in Sistan region, Iran.

## MATERIALS AND METHODS

This study was carried out at Research Farm of Faculty of Agriculture, Zabol University, Iran during 2008 to 2009 growing season; aiming to evaluate the effects of micronutrient foliar application on agronomic traits and oil content of safflower. The experiment was done using randomized complete block design with three replications. Safflower plants were subjected to nine treatments as: F1: control, F2: Fe (as $FeSo_4$), F3: Zn (as $ZnSo_4$), F4: B (as $H_3BO_3$), F5: Mn (as $MnSo_4$), F6: Fe+B, F7: Fe+Mn, F8: Fe+Zn and F9: Zn+B. Prior to experiment, a composite soil sample was taken from 0 to 30 cm soil depth of the experimental site and transferred to laboratory in order to the physical and chemical analysis described by Mylavarapu and Kennelley (2002). Soil texture was sandy loam with pH = 8.3. Other characteristics of the soil are given in Table 1. Climate of Sistan region is hot and dry with mean annual temperature and precipitation of 21.7°C and 55 mm, respectively.

Fe, Zn, Mn and B micronutrients were applied at the concentrations of 4, 3, 3 and 2 ml/l, respectively. These spray fertilizers were used at two times: 60 days after planting and 80 days after planting. Each experimental plot was included of 4 rows with 40 cm apart and 5 m long. Plants were sown with distances of 15 cm on each row. For reaching to optimum density, plants were sparse after the full establishment.

Irrigation and other agronomic practices such as weeds, pests and diseases control performed as recommended in the area and were done during growth season. Leaf chlorophyll content was measured by "SPAD 502" chlorophyll-meter system in the beginning of flowering stage. At harvest time, 5 plants of each plot were selected randomly and morphological characteristics and yield components were measured. To determine the biological yield and seed yield, after removing the border effect, safflower plants within 4 $m^2$ of each plot were harvested manually. Oil percent was determined by the Nuclear Magnetic Resonance (NMR) in the laboratory (Sinaki et al., 2007). Finally, all data were subjected to analysis of variance using SAS software. The means differences among the treatments were compared by Duncan Multiple Comparison Test at 0.05 level of probability.

## RESULTS AND DISCUSSION

### Leaf chlorophyll

Analysis of variance results indicated that the effect of micronutrients elements foliar application on leaf chlorophyll content was not significant (Table 2). Nevertheless, the results of means comparison indicated that F9 treatment (Zn+B) increased leaf chlorophyll content more than other treatments followed by F6 (combination of Fe and B) treatment (Table 3). Ghasemian et al. (2010) stated that zinc micronutrient is an essential element for chlorophyll synthesis. Babaeian

**Table 3.** Mean comparison of measured traits of safflower.

| Treatments | Leaf chlorophyll (SPAD) | Seed no. | 1000-seed weight (g) | Seed yield (kg/ha) | Harvest index (%) | Oil content (%) |
|---|---|---|---|---|---|---|
| F1 (control) | 144.3$^{a}$ | 23.86$^{a}$ | 29.63$^{b}$ | 675.3$^{c}$ | 22.96$^{a}$ | 21.19$^{ab}$ |
| F2 (Fe) | 154.8$^{a}$ | 27.67$^{a}$ | 39.94$^{a}$ | 1346.0$^{a}$ | 25.33$^{a}$ | 24.80$^{ab}$ |
| F3 (Zn) | 151.2$^{a}$ | 29.12$^{a}$ | 38.24$^{a}$ | 993.2$^{bc}$ | 24.12$^{a}$ | 21.50$^{ab}$ |
| F4 (B) | 142.4$^{a}$ | 27.36$^{a}$ | 38.11$^{a}$ | 963.7$^{bc}$ | 26.37$^{a}$ | 21.03$^{ab}$ |
| F5 (Mn) | 145.7$^{a}$ | 27.10$^{a}$ | 39.37$^{a}$ | 1042.3$^{ab}$ | 25.00$^{a}$ | 21.42$^{ab}$ |
| F6 (Fe+B) | 163.2$^{a}$ | 27.84$^{a}$ | 38.11$^{a}$ | 1215.8$^{ab}$ | 26.68$^{a}$ | 25.25$^{a}$ |
| F7 Fe+Mn) | 156.5$^{a}$ | 25.92$^{a}$ | 38.22$^{a}$ | 959.8b$^{c}$ | 25.08$^{a}$ | 21.75$^{ab}$ |
| F8 (Fe+Zn) | 150.9$^{a}$ | 25.78$^{a}$ | 37.37$^{a}$ | 913.0b$^{c}$ | 23.93$^{a}$ | 20.95$^{ab}$ |
| F9 (Zn+B) | 185.3$^{a}$ | 28.03$^{a}$ | 38.57$^{a}$ | 1024.1$^{ab}$ | 25.21$^{a}$ | 20.29$^{b}$ |

Mean followed by similar letters in each column are not significantly different at 5% level of probability.

et al. (2011) stated that chlorophyll content (SPAD value) was significantly higher when sunflower plants sprayed with Mn alone or in combination with Fe/Zn compared to the control.

**Number of seed per head**

The results of variance analysis showed that micronutrients foliar spray had no significant effect on the number of seed per head (Table 2). Nevertheless, the highest amount of number of this parameter (29.1) was obtained from foliar application of Zn (F3 treatment) followed by F9 treatment (28.03) that combination of Zn and B was used. The minimum number of seed per head (23.8) was recorded from control treatment (Table 3). Zinc element plays an important role in different metabolic processes in plant. Banks (2004) declared that foliar application of zinc fertilizer increased the number of seed per pod of soybean.

**1000-seed weight**

The analysis of variance (Table 2) revealed that 1000-seed weight significantly influenced in response to foliar application of micronutrients. The highest 1000-seed weight was obtained from Fe foliar treatment as compared to control; however, the difference between it and other foliar application treatments was not statically significant. Narimani et al. (2010) also found that all micronutrient treatments increased the seed number over control and no significant difference was observed between them in the case of seed number. This treatment caused 34.8% increase in 1000-seed weight compared to control (Table 3). The increase of yield components due to micronutrients application might be due to their positive effects on assimilates translocation, activation of photosynthetic enzymes, chlorophyll formation and improvement of plant growth (Pilbean and Kirkby, 1983; Movahhedi-Dehnavi et al., 2009).

**Seed yield**

Data presented in Table 2 shows that micronutrients foliar spray had a significant influence on seed yield of safflower. The highest amount of seed yield (1346 kg/ha) obtained from foliar application of Fe (F2 treatment) so that this treatment caused 99.32% increase in seed yield than control treatment (Table 3). Fe element by increase of plant photosynthesis and roots growth that lead to net photosynthesis improved seed yield (Lewis and McFarlane, 1986). After F3 treatment, application of F5 and F9 treatments increased seed yield more than other treatments. Results also illustrate that the lowest seed yield (675.3 kg/ha) was obtained from control treatment (Table 3). Singh et al. (1996) reported that application of $ZnSo_4$ significantly increased seed yield of sunflower. Increase of seed yield of safflower due to zinc foliar application has been reported by Movahhedi-Dehnavi et al. (2009). Micronutrient elements play a critical role in plants that lead to increase of leaf area index and thereby increased light absorption and increase the amount of dry matter accumulation and economic yield (Ravi et al., 2008).

**Biological yield**

The statistical analysis of the recorded data indicated the differences of the effects of foliar application treatments on biological yield of safflower at 5% level of probability was significant (Table 2). According to the means comparison results (Figure 1), biological yield was significantly higher in plants sprayed by Fe micronutrient fertilizer followed by foliar spray with Zn+B and Fe+B. Foliar application of Fe lead to 80% increase of biological yield compared to control. Positive effect of micronutrient elements on biological yield of safflower has been

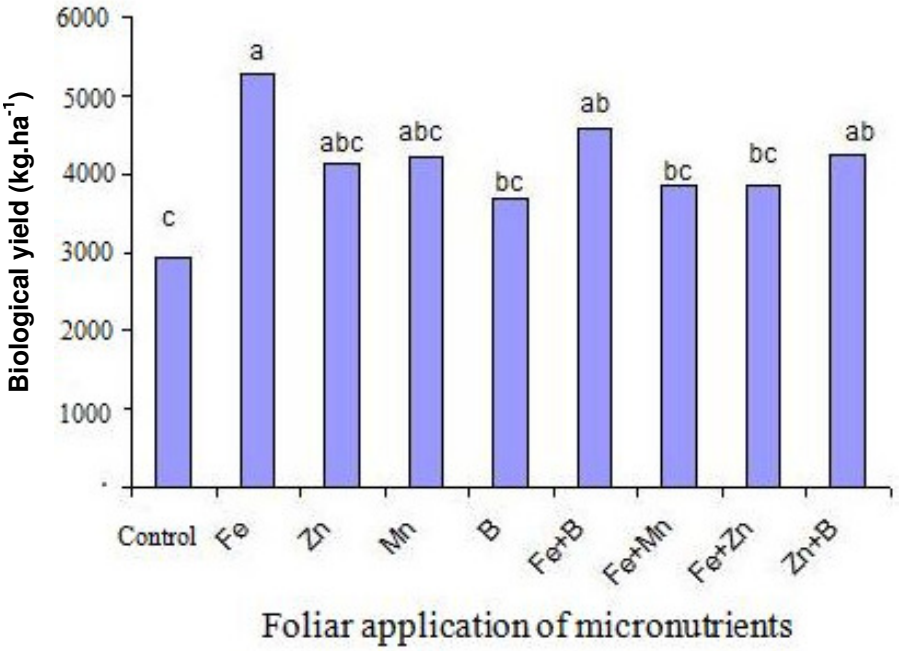


**Figure 1.** Effect of micronutrient elements foliar on biological yield.

reported by Movahedi-Dehnavi et al. (2009).

## Harvest index

Effect of micronutrients foliar application on the harvest index was not significant (Table 2); although the results of means comparison showed that foliar spray with micronutrients compared with control treatment achieved higher harvest index. Among foliar treatments with micronutrient elements, the highest harvest index (26.7%) obtained from foliar application of Fe+B (F6 treatment) compared to control treatment was about 16.2% higher (Table 3). Zareie et al. (2011) found that $FeSo_4$ increased biological yield of safflower; however its effect was not statically significant.

## Oil percentage

Spraying with micronutrients was effective on safflower seed oil percentage significantly (Table 2). The results showed that seed oil percentage in foliar treatments significantly was higher than control treatment. Among foliar application treatments, the highest oil percentage (25.25%) obtained from F8 (Fe+B) that was 19.16% higher compared to control (Table 3). Many researchers reported that micronutrient elements because of supplying plant need to these elements can lead to increase of seed oil percentage (Yari et al., 2004; Movahhedi-Dehnavi et al., 2009; Ravi et al., 2008). Due to the enzymatic activity enhancement, microelements effectively increased photosynthesis and translocation of assimilates to the seed (Heidaria et al., 2011).

## Conclusion

Results of this experiments revealed that spraying safflower plants with micronutrient significantly increased seed yield, biological yield, 1000-seed weight as well as seed oil content. Also, the other traits such as chlorophyll content, seed number per head and harvest index influenced by micronutrient application, although this effect was not statically significant. This positive effect may be due to their effects on root growth, nutrients uptake, simulation of many different enzymes related to photosynthesis and other physiological processes as well as multiple advantage of foliar application such as immediate and efficient response to plant nutrient requirement, uniform fertilization and independence of this method of soil conditions.

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