Effect of foliar application of Micro-nutrients on yield and yield components of safflower under conventional and ecological cropping systems

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Abstract

Information regarding the effect of foliar application of zinc and manganese on the yield and yield components of safflower (Carthamus tinctorius L. cv. Isfahan landrace) under conventional and ecological cropping systems is scarce. Therefore, a field experiment was conducted as split-plot based on Randomized Complete Block Design with three replications in 2011. Treatments were cropping systems (high, medium, low input and ecological cropping systems) as main plots and foliar application of micro-nutrients (no foliar application, 2000 ppm zinc chelate, 3000 ppm manganese chelate, 2000 ppm zinc chelate + 3000 ppm manganese chelate and water) as sub plots. Results of ANOVA showed significant effect of cropping system and foliar application on the number of seeds per head and number of heads per plant, and however significant interaction effect on 1000 seed weight, seed yield and biological yield. The highest 1000 seed weight (36.37 g), seed yield (4115.6 kg/ha) and biological yield (8175 kg/ha) were obtained from plants treated by zinc at high input cropping system. In all foliar sprays, there was a descending trend from along with decreasing inputs, so the minimum 1000 seed weight (20.76 g), seed yield (1540.3 kg/ha) and biological yield (3112.5 kg/ha) were obtained from ecological system. In conclusion, use of micronutrients, foliar application caused to improve the yield of safflower, especially in medium and low input systems.

Keywords: Biological yield, Carthamus tinctorius, Manganese, Zinc.

Introduction

Safflower (Carthamus tinctorius L.) is an important oilseed crop of the family Asteraceae 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 (Rahamatalia et al., 2001; Tahmasebpour et al., 2011). One of the most important issues about increase of crop yield and improving the quality of agricultural products is balanced plant nutrition. Foliar application of nutrients has become an efficient way to increase yield and quality of crops (Romemheld and El-Fouly, 1999). In arid and semiarid regions such as Iran, foliar application of nutrients is a more suitable option compared with soil fertilization when the roots cannot 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). Foliar application of micronutrients particularly Zn and Mn in small amounts had significant positive effect on 1000-seed weight, plant height, biological yield, grain yield, harvest index and
oil content of sunflower (Babaeian et al., 2011), and growth of rice (Wissuwa et al., 2008). Potarzycki and Grzebisz (2009) reported that zinc exerts a great influence on basic plant life processes, such as (i) nitrogen metabolism– uptake of nitrogen and protein quality; (ii) photosynthesis– chlorophyll synthesis, carbon anhydrase activity.

Zinc (Zn) is known to have an important role either as a metal component of enzymes or as a functional, structural or regulatory cofactor of a large number of enzymes (Grotz and Guerinot, 2006). Manganese (Mn) in turn, is regarded as an activator of many different enzymatic reactions and takes part in photosynthesis. Manganese activates decarboxylase and dehydrogenase and is a constituent of complex PSII-protein, SOD and phosphatase. Deficiency of Mn induces inhibition of growth, chlorosis and necrosis, early leaf fall and low reutilization (Kabata-Pendias and Pendias, 1999). Several researches indicated a positive influence of micronutrient (Zn, Mn) application in increase of yield and quantitative parameters of crops (Mosavi et al., 2007) on potato, (Paygozar et al., 2009) on pearl millet. Seifi Nadergholi et al. (2011) indicated that Zn and Mn foliar application noticeably raised common bean yield components. Berglund (2002) noted that Zn foliar application particularly increased soybean seed yield. Bozoglu et al. (2007) stated that foliar application of micronutrients (Zn) on chickpea could be implemented for higher yield and quality. Randall et al. (1970) reported that foliar application of 0.17 to 0.51 kg Mn-EDTA ha⁻¹ resulted in higher yield of soybean.

Conventional farming has played an important role in improving food and fiber productivity to meet human demands but has been largely dependent on intensive inputs of synthetic fertilizers, pesticides, and herbicides (Horrigan et al., 2002). This farming system cause to the reduction in biodiversity (Lupwayi et al., 2001; Oehl et al., 2004), environmental contamination (Horrigan et al., 2002), and soil erosion (Reganold et al., 1987). Public concerns over environmental health and food quality and safety have led to an increasing interest in alternative farming practices with both lower inputs of synthetic chemicals and greater dependence on natural biological processes. Organic farming systems avoid applications of synthetic fertilizers and pesticides, rely on organic inputs and recycling for nutrient supply, and emphasize cropping system design and biological processes for pest management (Rigby and Caceres, 2001). Yield losses due to nutrient limitation, pest damage, and weed pressure often occur during the transition period from conventional to organic systems following the immediate withdrawal of synthetic fertilizers, insecticides, fungicides, and herbicides (van Bruggen and Termorshuizen, 2003). Reganold et al. (2001) reported that an organic system had lower yields during the first 2 years of the organic transition. During the past two decades, organic agriculture has been on the rise in many parts of the world. However, despite this growth and the increased research, policy, media, and public attention, only a small share of the total agricultural land is under organic agriculture (e.g. 4% in Europe) (Eurostat., 2007).

One of the important obstacles to the conversion from conventional to organic farming is the possible reduction in yields (Berry et al., 2002). The yields in organic farming are restricted by a higher proliferation of weeds (Mason and Spaner, 2006) and diseases and in particular the lower input of nutrients (Murphy et al., 2007; L-Baekkstrom et al., 2004) and are dependent on the availability of N mineralized from organic manure and plant debris. The adoption of adequate rotations and management practices, such as weed control, crop residue treatment, use of catch crops, or an appropriate timing and amount of manure application determine the degree to which yields and nutrient losses are affected (Thorup-Kristensen et al., 2003; Rasmussen et al., 2006; Olesen et al., 2009).

Safflower has been evaluated as an alternative oil crop for organic farming in South West and North Germany since 2002. Safflower has a potential to be a promising oilseed crop in low-input farming system (Elfadl et al., 2009). In a long-term study that compared conventional, organic, and low-input farming systems in California all crops, except safflower, had significantly lower yields under organic conditions (Clark et al., 1999). Therefore, the purpose of this study is to recognize the effect of foliar application of micro-nutrients and different cropping systems on yield and yield components of safflower.

Materials and Methods

This experiment was conducted as split-plot, laid out in Randomized Complete Block Design with three replications at the Research Farm of Faculty of Agriculture, Urmia University, Urmia-Iran in 2011. Treatments were cropping systems as main plot (high, medium, low input and ecological cropping systems) and the foliar application of micro-nutrients as sub plot (no foliar application, 2000 ppm zinc chelate, 3000 ppm manganese chelate, 2000 ppm zinc + 3000 ppm manganese, and water). Agronomic practices (Tillage operations, Leveling,
Nitrogen and Phosphorus fertilizers, organic manure, weed and pest managements) for each cropping system were separately shown in Table 1. Some physico-chemical characteristics of soil were given in Table 2. Chemical analysis of manure experiment was given in Table 3. Seeds of safflower (Carthamus tinctorius L. cv. Isfahan landrace) were sown in soil at depth of 2 cm in plot sizes of 2.5 x 3 m, with plant spacing of 50 x 6 cm containing 330000 plants per hectare.

Foliar sprays were applied at 50% of flowering and repeated after two weeks. To determine the yield of seed and biological yield, plants were harvested from 1 m² of the three middle rows from each plot, and threshed manually. At harvest time, 5 plants of the three middle rows of each plot were randomly selected and the number of seeds per head, number of heads per plant was counted. 1000 seed weight was determined using four samples of 250 seeds. Data analysis of variance was done by SAS 9.1 software. The means differences among the treatments were compared by LSD Multiple Comparison Test at 0.05 level of probability.

**Results and Discussion**

Results of analysis of variance showed the significant effect of crop system (P≤0.05), foliar application (P≤0.01) on number of seeds per head (Table 4). Means comparison indicated that the maximum (41.09) and minimum (33.91) number of seeds per head was obtained from high input and ecological cropping system respectively. There was no significant difference between number of seeds per head obtained from medium and low input systems (Fig. 1A). There were some reported on increasing number of seeds in wheat (Hilderman et al., 2009) and rice (Puangsomlee Wangsomnuk et al., 2009) in conventional farming with chemical fertilizer more than organic farming.

The minimum number of seeds per head (33.91) was obtained in control treatment of foliar application and water spraying (34.62). While, foliar application with Zn+Mn caused to the maximum increasing in number of seeds per head (41.42) compared to control (Fig. 1B). It may be due the provision of nutrients to the crop at later growth stages which may have resulted in more number of seeds per head. Previously, Yousefi (2012) had reported the highest seeds number in pumpkin by foliar application of Zn and Mn. Similarly, some reports indicated marked increase in the number of seeds per spike in wheat Soleimani (2006), the number of seeds per pod in soybean (Banks, 2004) and seeds number per head in canola (Nabipour et al., 2009) by foliar application of micro nutrient.

However, there were significant effect of cropping system and micronutrient on the number of heads per plant (Table 4). Means comparison indicated that the high input cropping system caused to the most number of heads (6.94) followed by medium, low and ecological systems. So, the least number of heads per plant (4.82) was obtained from ecological cropping system (Fig. 2A). Delmotte et al. (2011) reported that the number of panicles in rice was greater under conventional management. Also, (Ahmadi and Bohrani, 2009) and (Jouyban and Moosavi, 2012) found that the number capsules per plant increased in sesame cultivars with higher nitrogen usage compared to control.

The maximum number of heads per plant (6.83) was obtained from Zn+Mn spraying followed by Zn application. The minimum number of heads per plant was observed at water spray (5.10) and no foliar application (5.13) (Fig. 2B). Results of Nabipour et al. (2009) revealed that the number of heads per plant was improved by Mn spraying at flowering and pollination stages.

Results of analysis of variance showed the significant interaction effect between cropping system and foliar application (P≤0.01) on 1000 seed weight (Table 4). Zinc use in high input systems caused to increase the weight of seeds, so that the most weight of 1000 seed (36.37 g) were obtained from high input cropping system and Zn spray as well as Zn+Mn. This treatment caused 42.92 % increase in 1000-seed weight compared to ecological crop system and no foliar application. The minimum 1000 seed weight (20.76 g) belonged to ecological cropping system and no foliar application (Fig 3). So, 42.92 % of rising in 1000 seed weight was observed by micronutrient use under high input systems compared to ecological condition (without chemical input).

The increase of 1000 seed weight 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 (Pilebean and Kirkby, 1983; Movahhedi-Dehnavi et al., 2009). In contrast to our findings, there were no significant differences between organically and conventionally grown (Triticum aestivum L.) for 1000 seed weight (Mader et al., 2007; Schwaerzel et al., 2006).

Cropping system and foliar application of micro-nutrients and their interaction had significant effect on seed yield (Table 4). The highest (4115.6 kg/ha) yield of seed was obtained from high input cropping system and...
Zn spraying. The lowest (1540.3 kg/ha) seed yield was obtained from ecological cropping system and water spray. These results showed 62.57% increasing of seed yield in high input cropping system and Zn spraying more than ecological cropping system and water spray (Fig. 4). In conventional cropping system, yield increase has generally been accompanied by an increased input of external resources such as mineral fertilizers (Tilman et al., 2002; Stickel et al., 2000). Also, increase in seed yield was associated with increases in number of seed per head (Fig 1-A and 1-B). Generally, plant yields are lower under organic conditions than conventional conditions, due to low soil nutrient status (slow release of organic fertilizers) and the pressure from weeds, pests and diseases (L-Baekstrom et al., 2006; Mader et al., 2002; Schwaerzel et al., 2006). Higher yield of wheat (L-Baekstrom et al., 2006; Schwaerzel et al., 2006) and rice (Delmotte et al., 2011) were obtained under conventional conditions than organic conditions, previously. But, Poudel et al. (2002) in corn and tomato and Posner et al. (2008) in soybean reported no difference between conventional and organic systems for economic yield. This superior of high input systems were 10 - 41 % in maize (Cavigelli et al., 2008; Posner et al., 2008), 35 % in cereal (Eltun et al., 2002; Denison et al., 2004).

Increase of seed yield of safflower due to zinc foliar application has been reported by (Movahhedi-Dehnavi et al., 2009). On the other hand, micronutrients increases photosynthesis rate and improves leaf area duration thus seed yield will be increased (Cakmak, 1999). 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).

Data in Table 4 showed the significant interaction of cropping system and foliar application on biological yield. High input cropping system with foliar application Zn caused to 61.92 % increase in biological yield compared to ecological system and water spray as well as no foliar application (Fig. 5). Results of a two-year experiment by Pospisil et al. (2006) achieved cropping system had no influence on dry matter mass of leaf and stem in soybean plant in first year, while higher dry matter mass of leaf and stem was recorded in second year of experiment in the high-input system.

Frequency of nitrogen in high input cropping system can increase vegetative growth, expand leaf area and its durability and also increase branch production, by which biological yield is increased (Ahmadi and Bohrani, 2009; Paperi Moghadam Fard and Bohrani, 2005). Increase in biological yield in wheat (Soleimani, 2006; Torun et al., 2001) and oilseed rape (Grewal et al., 1997) reported due to dry matter production for application of micronutrients over control. Positive effect of micronutrient elements (Zn, Mn) on biological yield of safflower has been reported by (Movahhedi-Dehnavi et al., 2009).

### Table 1. Amount of inputs consumed and agronomic measures necessary in different cropping systems

<table>
<thead>
<tr>
<th>Inputs</th>
<th>High input</th>
<th>Medium input</th>
<th>Low input</th>
<th>Ecological</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tillage operations</td>
<td>Plow+ rummage soil with a shovel</td>
<td>Plow</td>
<td>Plow</td>
<td>Plow</td>
</tr>
<tr>
<td>Leveling</td>
<td>Rake</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>*N fertilizer (kg/ha)</td>
<td>180</td>
<td>120</td>
<td>60</td>
<td>-</td>
</tr>
<tr>
<td>*P fertilizer (kg/ha)</td>
<td>120</td>
<td>80</td>
<td>40</td>
<td>-</td>
</tr>
<tr>
<td>Manure (t/ha)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>40</td>
</tr>
<tr>
<td>Herbicide (time)</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Herbicide (time)</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>Weeding out</td>
</tr>
</tbody>
</table>

* Nitrogen from urea and Phosphorus from triple superphosphate

### Table 2. Chemical analysis of soil of experimental site without manure

<table>
<thead>
<tr>
<th>Texture</th>
<th>O.C (%)</th>
<th>N (%)</th>
<th>P (ppm)</th>
<th>K (ppm)</th>
<th>Zn (ppm)</th>
<th>Mn (ppm)</th>
<th>EC (dS/m)</th>
<th>pH</th>
<th>Clay (%)</th>
<th>Silt (%)</th>
<th>Sand (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clay loam</td>
<td>0.94</td>
<td>0.094</td>
<td>11.6</td>
<td>395</td>
<td>4.26</td>
<td>2.8</td>
<td>0.54</td>
<td>8.21</td>
<td>32</td>
<td>37</td>
<td>31</td>
</tr>
</tbody>
</table>

### Table 3. Chemical analysis of soil experimental site with manure
Table 4. Analysis of variance of yield and yield components affected by foliar application of micro-nutrients and different cropping systems on yield and yield components in safflower

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>df</th>
<th>Number of seeds per head</th>
<th>Number of heads per plant</th>
<th>1000 seed weight</th>
<th>Seed yield</th>
<th>Biological yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replication</td>
<td>2</td>
<td>49.85*ns</td>
<td>2.25*ns</td>
<td>3.32</td>
<td>1023754.61*ns</td>
<td>4428178.31*ns</td>
</tr>
<tr>
<td>Cropping system(A)</td>
<td>3</td>
<td>129.96*</td>
<td>11.91*</td>
<td>160.94**</td>
<td>6728524.67**</td>
<td>17566534.38**</td>
</tr>
<tr>
<td>E_a</td>
<td>6</td>
<td>25.15</td>
<td>1.25</td>
<td>0.46</td>
<td>455749.64</td>
<td>950760.93</td>
</tr>
<tr>
<td>Foliar application(B)</td>
<td>4</td>
<td>122.03*</td>
<td>7.26*</td>
<td>183.15**</td>
<td>1655423.25**</td>
<td>8608836.06**</td>
</tr>
<tr>
<td>A×B</td>
<td>12</td>
<td>8.84*ns</td>
<td>0.306*ns</td>
<td>3.12**</td>
<td>300024.88</td>
<td>790403.94*</td>
</tr>
<tr>
<td>E_b</td>
<td>32</td>
<td>8.30</td>
<td>0.507</td>
<td>0.667</td>
<td>115731.16</td>
<td>368474.2</td>
</tr>
<tr>
<td>Coefficient of variance (%)</td>
<td>7.67</td>
<td>12.12</td>
<td>2.84</td>
<td>12.74</td>
<td>11.85</td>
<td></td>
</tr>
</tbody>
</table>

ns, * and ** non-significant, significant at 0.05 and 0.01 probability, respectively.

Figure 1. Means comparisons of the number of seeds per head affected by cropping system (A) and foliar application of micronutrient (B) in safflower. The same letters show no differences between treatments (Ps0.05).
Figure 2. Means comparisons of the number of heads per plant affected by cropping system (A) and foliar application of micronutrient (B) in safflower. The same letters show no differences between treatments ($P \leq 0.05$).

Figure 3. Means comparisons of 1000 seed weight affected by cropping system and foliar application of micronutrient in safflower. The same letters show no differences between treatments ($P \leq 0.05$).
Conclusion

Results of this research revealed that micronutrient spraying of safflower plants significantly increased seed yield, biological yield, and 1000-seed weight under high input cropping system as followed by medium and low input. This improve was obtained because of positive effect of zinc and manganese on the number of seeds per head and number of heads per plant. Frequency of nitrogen, good preparation of soil, pest and weed control in high input cropping system caused to enhance biological yield, that it can improved the yield of seed and 1000 seed weight. Micronutrient use led to higher yield and yield components in low and medium input systems compared to water spraying and control treatment. Even, in high and medium systems, we obtained the same
yields (seed and biomass) by Zn+Mn foliar application. In conclusion, we can improve the yield of safflower in ecological and low input systems by incorporating micronutrients.

References


