Evaluation the effect of water stress and foliar application of Fe nanoparticles on yield, yield components and oil percentage of safflower (Carthamus tinctorious L.)

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ABSTRACT

To study the impact of iron nanoparticles foliar application on mitigating the effects of drought stress on yield, yield components and oil percentage of Goldasht spring safflower cultivar, an experiment was carried out in 2012 in the Agricultural Research Farm Station of Islamic Azad University, Roudehen branch as split plot in a completely randomized blocks design with three replications. In this experiment, the major factor of drought stress treatment included four levels (optimum irrigation, stopping the irrigation at flowering stage, stopping the irrigation at seed formation stage and stopping the irrigation at two stages of flowering and seed formation). After data analysis by SAS software, the parameters including analyses of variance and means were compared using the Duncan's Multiple Range Test at probability level of 5%. The results showed that the effects of drought stress and Fe nanoparticles were significant at probability level of 1% on traits such as the number of boll per branch, number of seeds per boll, the thousand seed weight and yield at probability level of 1%. Among the levels of drought stress, the highest yield and yield components losses were seen for most of the traits and between the levels of 2 times drought stress. The maximum yield and yield components rates related to the control treatment (optimum irrigation). Also, among the levels of Fe nanoparticles, the use of nanoparticles produced the highest rates of yield and yield components in two stages of flowering and granulation. Also, the foliar application at flowering stage was better than seed formation. Meanwhile, the control treatment had the lowest yield and yield components. Finally, the interactions of Fe nanoparticles and different levels of drought stress at 1% probability level had significant impacts on traits, including boll number per branch, number of seeds per boll, the thousand seed weight and the yield. At the end of the experiment, the 2 times stress had the highest yield and yield components losses, and 2 times of using nanoparticles had the highest rates of yield and yield components. Thus, the adverse effects of drought stress can be reduced in this area and similar areas by application of Fe nanoparticles.

Keywords: safflower (Carthamus tinctorious L.); Water stress; Fe nanoparticles: Yield; Yield Components; Oil Percentage.

Introduction

Iran's annual consumption of oil is about one million tons that only 10% of them are produced in the country and the rest is imported from abroad. Increasing trend of per capita consumption of vegetable oils, increased imports and a cost of 800 million dollars per year to provide the deficit in the supply of vegetable oil and oilseed meal are as important factors indicating the need to develop oilseed crops and the development of scientific and research programs in this context. Among the oilseeds compatible with Iran's climate, the safflower has a special status, which is well-suited in areas with water shortages. Safflower as a native plant to Iran, with its relatively high tolerance to drought and salinity as well as having oil with a high quality can play an important role in developing oilseeds acreage in the country (Frozan, 1997). Safflower (Carthamus tinctorious L.) is from a composite family with full foliage, which is herbaceous, semi-barbed and one-year age with a height varying from 20 to150 cm. Its flowers are usually yellow, orange and red. The seed oil content and protein content is 27-40% and 15-19%, respectively, and its seeds are like sunflower small eggs botanically called Hackin. More than 82 percent of Iran's lands are located in arid and semi-arid regions of the world. One of the main factors to limit crops production in arid and semi-arid regions is the water deficit stress. Water shortage occurs in plant when transpiration and water disposal rates are more than its absorption. As a result, a combination of physical and environmental factors lead to tension within the plant due to caused drought, and finally will reduce the production. Proper nutrition under stress conditions could partly help the plant to tolerate different stresses. Micronutrient elements play a vital role in plant growth and development and have an important contribution due to their necessity in increasing crop yield (Dewal & Pareek, 2004). Among sixteen food elements required by plants, the seven elements, including iron, zinc, manganese, copper, molybdenum and chlorine are needed in very quantities by the plants and are called as micronutrients for the same reason. The roles of these elements are summarized in the following:

Increased production per unit area

Improving the quality of products

Enrichment of agricultural products

Production of seed with higher germination and growth ability

Reduced pollutant concentrations in crops

Iron deficiency in plants leads to significant changes in plant metabolism and causes chlorosis. Elements absorption in plants under drought stress may have an important role in drought tolerance (Samarah, et al., 2004). Research has shown that the application of micronutrients can decrease the effects of environmental stresses such as drought stress and salinity stress (Wang et al., 2004). The plant roots are the primary organs responsible for nutrients uptake. The presence of a factor limiting the availability of nutrients in the soil will reduce the expected use of fertilizers. Under these conditions, the nutrients for plants can be obtained by foliar application (Altındişli et al., 1998). Foliar fertilization or foliar application actually includes spraying nutrients to the leaves and stems of plants and uptake of them from such places (Kuepper, G., 2003). Foliar application can guarantee access the plants to the nutrients to achieve high yield. From an ecological perspective, foliar fertilization is more acceptable, since lower values of nutrient elements are provided for immediate consumption by plant (Stampar et al., 1998).

Materials & Methods

The experiment was performed in May, 2012 under field conditions at research farm station, Islamic Azad University, Roodehen branch, located Garmabard village (affiliated to the city of Damavand). In this experiment, the Safflower seeds provided from the Seed and Plant Improvement Institute, Karaj, were grown in field conditions, so that the order of treatments in each block was determined in a completely

randomized pattern by drawing. Also, to eliminate the border effect, an area of 05 m of each of the side plots was not implanted. In this experiment, the Fe nanoparticles treatment including four levels (not using fertilizers (control), fertilization in flowering stage, fertilization in seed formation stage and fertilization in both phases) and also the drought stress treatment with 4 levels (optimum irrigation, water stress at flowering stage, stress in seed formation stage and stress in both stages) were determined as first factors (minor factors) and second factors (major factors). The research was performed during a split plot test in the form of completely randomized blocks design with three replications. Laboratory analyses of the farm soil sampled from the depth of 0-30 cm were transferred to the Soil Science laboratory and were analyzed based on common laboratory methods. Deep plowing was done in the previous autumn, and phosphate and phosphate fertilizers were also applied. Land preparation for the spring was done as cut and stack that the distance between rows (stacks) was 50 cm, and the distance between plants in each row was predicted as 15 cm. Each plot consisted of four rows, each 4 m long, and the last plot had 2 additional lines as border (to remove border effects). Harvesting was done as the custom in the area and based on standards. Also, the treatments were applied based on designed scheduling. After crop ripening, 1 m of each plot was harvested and yield was evaluated in terms of kilograms per hectare. The yield components including, the number of subsidiary branches, boll number per branch, number of seeds per boll, the thousand seed weight, and finally, the percentage of oil were measured.

Results & Discussion

The boll number per branch

The variance analysis results of boll number per Safflower branch showed that the main effect of Fe nanoparticles treatment and drought stress treatment and their interactive effects on the boll number in each branch were significant at the 1% probability level (Table 1). The comparison of the trait means showed that the use of Fe nanoparticles alone increased the number of boll per branch of Safflower. The highest rate had occurred due to use of Fe nanoparticles fertilizer at flowering and granulation stages (6.389), while the lowest rate was in the control treatment (5.968) (Table 2). The comparison of the trait means showed that the drought stress alone reduced the number of boll in each branch of Safflower by applying stress at various developmental stages. Its maximum rate was in the control treatment (6.881) and its lowest rate was at the treatment of water shortage stress in both flowering and granulation stages (5.179) (Table 2). The mutual use of both studied factors according to the results of the means comparisons indicated that the consumption of Fe nanoparticles in flowering and seed formation stages and the lack of stress applying (optimum irrigation) compared to other treatments discussed led to maximum number of boll per branch in under stress treatments (7.333). Also, the minimum number of boll in any branch was related to the use of Fe nanoparticles at granulation stage and applying drought stress in the granulation stage and applying drought stress at both flowering and seed formation stages (4.51) (Figure 1). It can be concluded that the use of Fe nanoparticles at flowering and seed formation stages as well as non-applying stress (optimum irrigation) has been able to increase the number of boll per branch. The positive role of micronutrient fertilizers like iron on the number of boll produced by safflower plants was also reported by Bibordi (2004). Reduced number of boll on branches due to the effect of irrigation stop and drought stress incidence have been reported in Abel (1976) and Haydari & Assad (1998) studies. They concluded that failure to provide the required water at different growth stages and the occurrence of drought stress on safflower crop will lead to decreased boll number per branches.

Table 1- Source of variation, degree of freedom and mean square on seed yield, No of seed per boll, No of boll per stem,1000seed weight and oil percentage.

S.O.V	df	Means of square (MS)				
		Oil (%)	1000 Seed weight	No of seed per boll	No of boll per stem	Seed yield(kg/hac)
Replicating	2	89/429**	77/58**	23/805**	19/688**	3438/738ns
(A) Fe application	3	11/735**	10/859**	92/114**	0/384**	68720/049**
Error a	6	1/103	0/332	0/932	0/008	1886/598
(B) Drought stress	3	6/643**	31/383**	119/673**	6/412**	527088/107**
(A×B)	9	0/592*	0/91**	9/344**	0/469**	27816/581**
Error	24	0/198	0/165	0/293	0/042	1857/647
C.V (%)	-	1/33	1/23	1/82	3/33	4/27

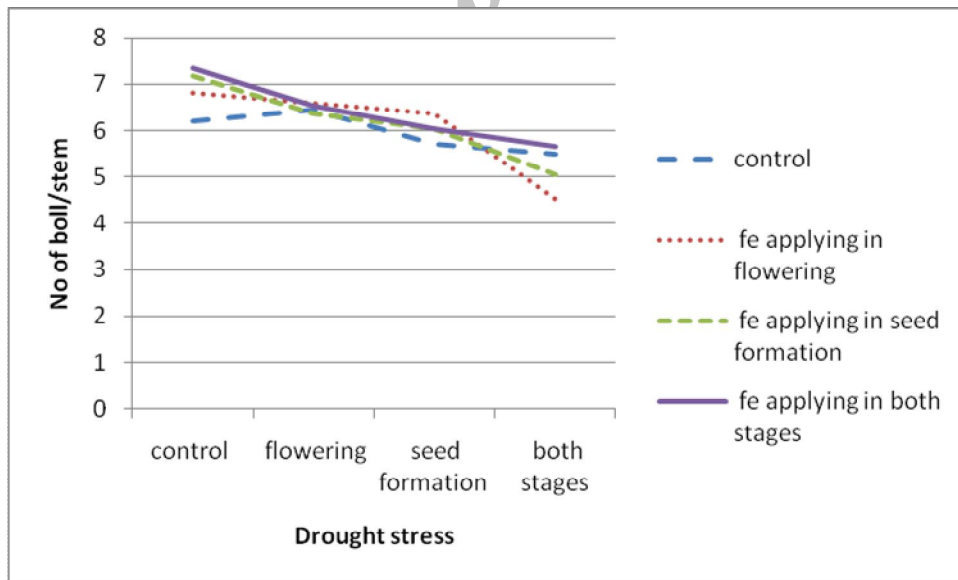ns, * and **: non significant, significant at the 5% and 1% levels of probability, respectively.

Figure 1: The Interaction effect of Fe nano particles and drought stress on boll number per branch in Safflower.

Number of seeds per boll

The variance analysis results of Safflower seed number per boll showed that the main effects of using Fe nanoparticles, drought stress and their mutual effects on seed number per boll was significant at 1% probability level (Table 1). The trait means comparison showed that consumption of Fe nanoparticles alone increased the Safflower seed number per boll. The maximum increase rate occurred due to use of Fe nanoparticles at flowering and seed formation stages (33.02), and its lowest rate was in the control treatment (26.55) (Table 2). Also, the drought stress alone caused the reduction in the Safflower number of seeds per boll at various developmental stages by applying stress that the highest rate was in the control treatment (32.76) and the lowest rate was in the water stress treatment at both flowering and seed formation stages (26.03) (Table 2). The mutual use of both studied factors according to the results of the means comparisons indicated that the consumption of Fe nanoparticles in flowering and seed formation stages and the lack of stress applying (optimum irrigation) compared to other treatments discussed led to maximum number of boll per branch in under stress treatments (35.1). Also, the minimum number of boll in any branch was related to the use of Fe nanoparticles at granulation stage and applying drought stress in the granulation stage and applying drought stress at both flowering and seed formation stages (21.93) (Figure 2). It can be concluded that the use of Fe nanoparticles at flowering and seed formation stages as well as non-applying stress (optimum irrigation) has been able to increase the number of boll per branch. The positive role of micronutrient fertilizers like iron on the number of boll produced by safflower plants was also reported by Bibordi (2004). Reduced number of boll on branches due to the effect of irrigation stop and drought stress incidence have been reported in Abel (1976) and Haydari & Assad (1998) studies. They concluded that failure to provide the required water at different growth stages and the occurrence of drought stress on safflower crop will lead to decreased boll number per branches.

Figure 2: The Interaction effect of Fe nano particles and drought stress on grain number in each of the Safflower bolls.
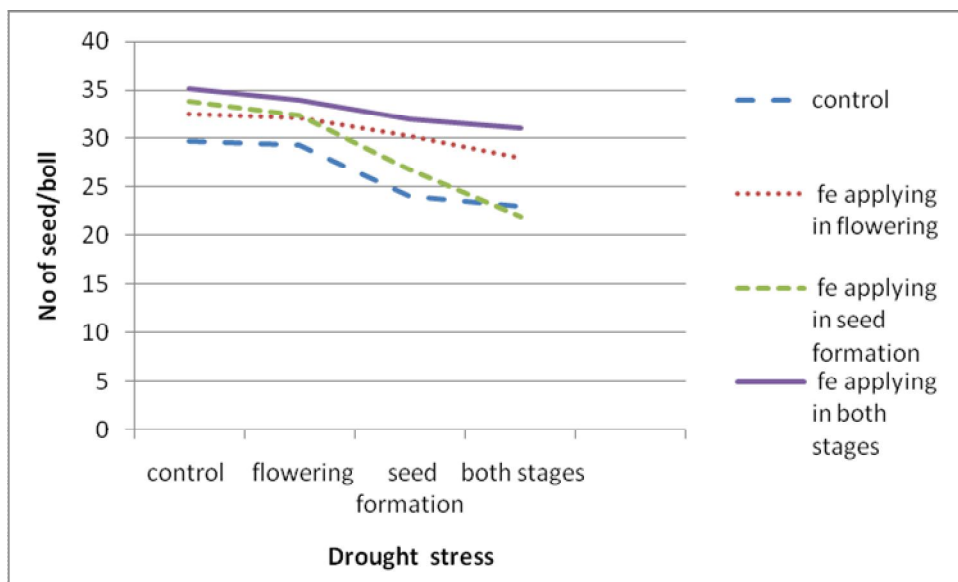

Table 2: Comparison the average of main effect of Fe nano particles and drought stress different levels factor on measured traits.

Treatments	Traits				
	Oil (%)	Seed yield(kg/hac)	1000 Seed Weight(gr)	No of seed per boll	No of boll per stem
Drought stress					
control	34/29a	1249a	35/13a	32/76a	6/881a
flowering	33/07bc	896/9c	33/22ab	28/29b	6/05b
seed formation	33/59ab	1109b	31/95b	31/95a	6/49a
In both stages	32/55c	781/7d	31/53b	26/03c	5/179c

Fe application					
control	30/07d	865d	31/54b	26/55d	5/968b
flowering	34/07c	1080b	33/3a	30/74b	6/166ab
seed formation	37/6b	1008c	32/45ab	28/72c	6/077ab
In both stages	39/5a	1183a	34/2a	33/02a	6/389a

Means followed by similar letters in each column are not significantly different at 5%, level of probability using Duncan test.

The thousand seed weight

The variance analysis results of Safflower thousand seed weight showed that the main effects of using Fe nanoparticles, drought stress and their mutual effects on the thousand seed weight was significant at 1% probability level (Table 1). The trait means comparison showed that the use of Fe nanoparticles alone increased the Safflower thousand seed weight that the maximum use occurred due to using Fe nanoparticles treatment in both flowering and seed formation stages (34.2 g), while the lowest rate was in the control treatment (31.54) (Table 2). Also, the drought stress alone caused the reduced Safflower thousand seed weight by applying stress at various developmental stages. Its highest rate was in the control treatment (35.13 g), while the lowest rate occurred in water stress treatment at both flowering and seed formation stages (31.53 g) (Table 2). The mutual application of both studied factors according to the results of mean comparisons showed that the use of nanoparticles treatment in both flowering and seed formation stages and non-applying the drought stress (optimum irrigation) compared to other treatments discussed led to the highest thousand seed weight in under stress treatments (35.51 g). Also, the lowest thousand seed weight was related to not using Fe nanoparticles fertilizers and drought stress at both flowering and seed formation stages (30.05 g) (Figure 3). It can be concluded that the use of nanoparticles treatment in both flowering and seed formation stages and lack of drought stress (optimum irrigation) had an increasing effect on the thousand seed weight. Malakoti & Nafisi (1995) suggested that the adequate presence of nutritional micronutrients in plant tissues and their transfer to the seed increases the thousand seed weight. The reduced thousand seed weight can be due to lack of food elements for grain filling due to irrigation stop at both steps. Reduction in thousand seed weight due to drought stress was seen in others' experiments, including Mozaffari et al. (1996).

Figure 3: The Interaction effect of Fe nano particles and drought stress on the thousand seed in safflower plant
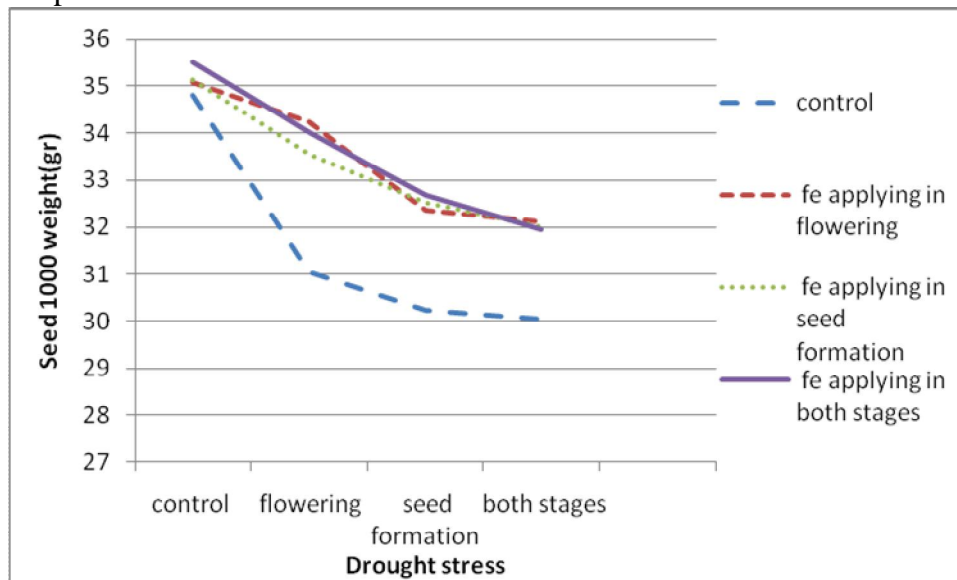

Yield

The variance analysis results of the Safflower yield rate showed that the main effects of using Fe nanoparticles, drought stress and their interactions on the yield rate was significant at 1% probability level (Table 1). The trait means comparison showed that consumption of Fe nanoparticles alone improved the Safflower yield rate that the highest rate was due to use of Fe nanoparticles fertilizers at flowering and seed formation stages (1183 kg per hectare) and its lowest rate was in the control treatment (865 kg per hectare) (Table 2). Also, the drought stress alone reduced the Safflower yield rate by applying stress at various developmental stages. Its maximum rate was in the control treatment (1249 kg per hectare) and its lowest rate was at the treatment of water shortage stress in both flowering and granulation stages (781.7 kg per hectare) (Table 2). The mutual use of both studied factors according to the results of the mean comparisons indicated that the consumption of Fe nanoparticles in the flowering stage and the lack of stress applying (optimum irrigation) compared to other treatments discussed led to maximum yield rate in under stress treatments (1382 kg per hectare). Also, the minimum yield rate was related to the use of Fe nanoparticles at granulation stage and applying drought stress at both flowering and seed formation stages (722.3 kg per hectare) (Figure 4). It can be concluded that the use of Fe nanoparticles at flowering stage as well as non-applying stress (optimum irrigation) has been able to increase the yield rate. The increased safflower seed yield rate in drought stress condition and using iron chelate can be due to the influence of this element on the activity of antioxidants enzymes (Giardi et al., 1997). Wiersma (2005) reported that soil application of Fe-EDDHA (Sequestrine 138) can largely resolve the chlorosis and increase the seed yield in soybean. Ziaeian & Malakoti (1998) also reported that soil and foliar application of micronutrients of iron, zinc, manganese and copper in corn nutrition causes the increased grain yield that the positive role of iron and zinc was more than manganese and copper in increasing the yield.

According to Rostami et al. studies (2003), applying water stress at vegetative growth stage of the plant seems to be resulted in shrinkage leaf area and reduced LAI per area unit. Thus, at this stage, reduced yield occurs due to reduced number of seeds per boll.

Figure 4: The Interaction effect of Fe nano particles and drought stress on seed

yield in safflower

Oil percentage
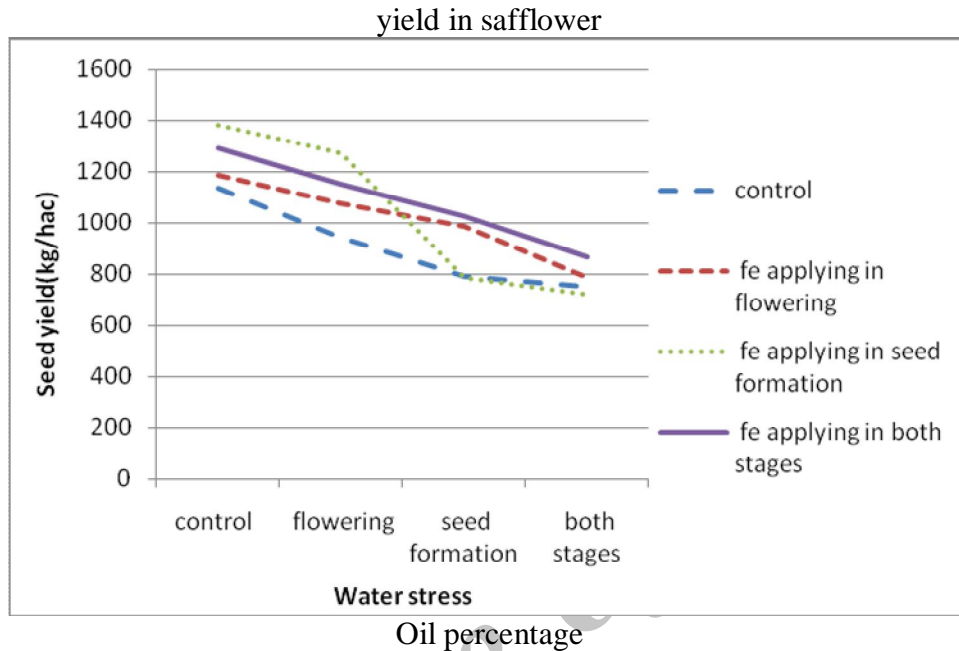
The variance analysis results of Safflower oil content showed that the main effects of Fe nanoparticles and drought stress were significant at 1% probability level and their interactive effects on the oil content were significant at 5% probability level (Table 1). The trait means comparison showed that consumption of Fe nanoparticles alone increased the Safflower oil content. The maximum increase rate occurred due to use of Fe nanoparticles at flowering and seed formation stages (39.5%), and its lowest rate was in the control treatment (30.07%) (Table 2). Also, the drought stress alone caused the reduction in the Safflower oil content at various developmental stages by applying stress that the highest rate was in the control treatment (34.29%) and the lowest rate was in the water stress treatment at both flowering and seed formation stages (32.55%) (Table 2). The mutual use of both studied factors according to the results of the means comparisons (figure 5) indicated that the consumption of Fe nanoparticles at flowering and seed formation stages and the lack of stress applying (optimum irrigation) compared to other treatments discussed led to maximum oil content in under stress treatments (35.64%). Also, the minimum oil content was related to the not using of Fe nanoparticles and applying drought stress at both flowering and seed formation stages (31.57%). It can be concluded that not using of Fe nanoparticles at flowering and seed formation stages as well as non-applying stress (optimum irrigation) has been able to increase the oil content.

Figure 5: The Interaction effect of Fe nano particles and drought stress on Safflower Oil percentage.
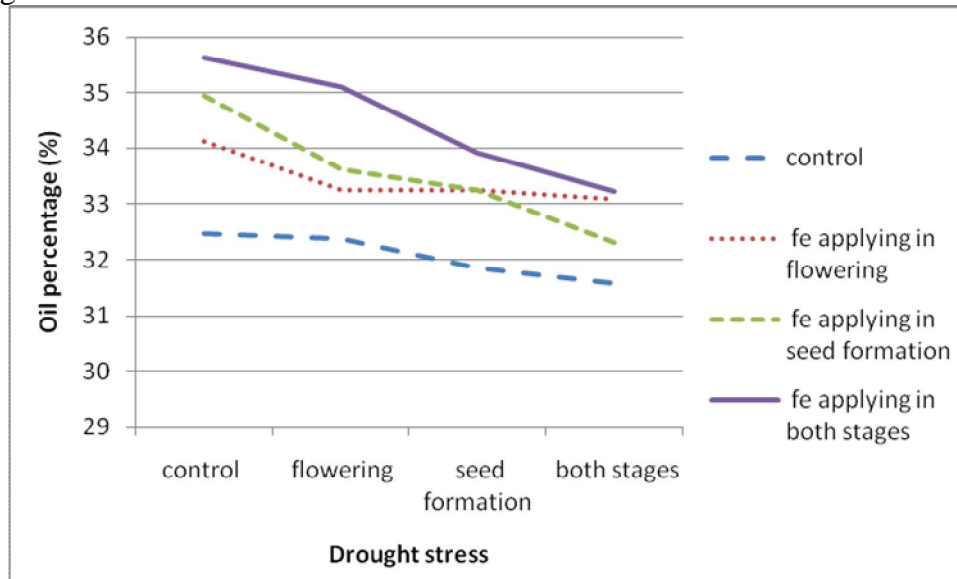
Increased activity of antioxidant enzyme due to consumption of iron chelate, especially in drought stress conditions, could sustain cell membranes and increase the capacity of the plant photosynthetic system; since through this, it can reduce damages due to oxidative stress, which results in increased chlorophyll content, increased grain yield and consequently, increased oil yield. Naderi Darbaghshahi et al. (2006) suggested that under drought stress in safflower, the oil yield dramatically decreases. However, with increasing the stress intensity at next levels, the yield drop occurs with less intensity. In their research, the oil yield was influence by drought stress and was significant at 1% probability level.

Conclusion

Finally, micronutrient fertilizers use (at both flowering and seed formation stages) could positively influence the studied factors in exposure to the drought stress. Thus, the stress at flowering and seed formation stages was associated with the highest values of studied in comparison with applying stress without using such fertilizers factors under the influence of using Fe nanoparticles.

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