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Effect of Iron Foliar Fertilization on Growth, Seed and Oil Yield of Sunflower Grown under Different Irrigation Regimes

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Abstract: This study was conducted in order to evaluate of effect of iron sulfate foliar application on yield and some agronomic traits of two sunflower cultivars under drought stress conditions. The experiment was carried out in 2009 growing season in the Agricultural Research Station of Eastern Azerbaijan. The experiment was RCBD with split plot arrangement with three replications. The main factor included three levels of drought stress (irrigation after 40, 60 and 75% soil water depletion from field capacity) sub factor included two sunflower cultivars and sub-sub factor included iron sulfate solutions (0, 2 and 4 part per thousand). Following traits were assayed in this study; plant height, stem diameter, leaf dry weight, stem dry weight, total dry weight, leaf area, 1000 seed weight, seed yield and oil yield. Analysis of variance showed significant difference among different levels of drought stress and also different concentration of iron sulfate on above mentioned traits. The results showed that there was no significant difference between two cultivars. In general, drought stress led to decrease of vegetative growth, seed and oil yield, while iron foliar application significantly improved dry matter production and finally increased seed and oil yield. So iron sulfate foliar application (4 part per 1000) is recommended in sunflower farms under normal and drought stress conditions.

Key words: Sunflower · Iron · Water stress · Seed yield · Oil yield

INTRODUCTION

Water is the most important and vital commodity on which whole life depends. It constitutes 90% of living cells and covers 75% area of the earth. Agricultural productivity is dependent upon water and it is essential at every stage of plant growth, from seed germination to plant maturation [1]. As a result of water deficit stress, the physiology of crop is disturbed this causes a large number of changes in morphology and anatomy of plant. These changes have different effects on growth and yield of the crop [2, 3]. Among various factors responsible for the low yield, the water requirement for the crop is the most important because water has a direct relationship with the yield of crop as reported by Karam [4]. That, increase in the irrigation interval reduced seed yield, plant height, head diameter, seed index and seed oil content and also increased the percentage of unfilled seeds. Reddy *et al.* [5] reported that, low yielding genotypes showed the least reduction in leaf area per plant, seed yield and total dry matter production due to moisture stress. Anwar [6] stated that, all the yield components were affected by the number of irrigations. Soriano *et al.* [7] concluded that sunflower seed yield was the most sensitive to water stress after anthesis. He also emphasized the need of irrigation management under limited water supply, especially during the reproductive period.

Fertilization is an effective practice for the application of some micronutrients, since it uses low rates and the micronutrient does not directly contact the soil, avoiding losses through fixation [8]. However, the narrow limit between phytotoxicity and deficiency brings the need for defining appropriate rates to be used. Even on the world scale, it is estimated that Fe deficiency is widespread occurring in about 30 and 50% respectively of cultivated soils [9]. Iron is critical for chlorophyll formation and photosynthesis and is important in the enzyme systems and respiration of plants [10]. Iron deficiency exhibited in citrus, deciduous fruits, groundnuts and many other crops [11]. They further stated that micro nutrients improves the crop quality and increases resistance in plants against biotic and abiotic stresses.

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Iron deficiency is a plant disorder also known as chlorosis. A deficiency in the soil is rare but iron can be unavailable for absorption if soil pH is not between about 5 and 6.5. A common problem is when the soil is too alkaline (the pH is above 6.5). Elements like calcium, zinc, manganese, phosphorus, or copper can tie up iron if they are present in high amounts. Iron functions to accept and donate electrons and plays important roles in the electron-transport chains of photosynthesis and respiration so it plays a role in energy transfer within the plant. Iron is a constituent of certain enzymes and proteins. In addition, Iron functions in plant respiration and plant metabolism.

Sunflower is the most important oil crop in Iran as well as in some other parts of the world. Sunflower is commonly regarded as a plant that is tolerant to water stress. Nevertheless, the crop consumes a large amount of water due to the fact that it produces high yields and a large vegetative mass [12, 13]. Sunflower is the most susceptible to soil water deficiency at flowering, fertilization and grain fill, whereas at the start and end of the growing period the sensitivity is not so evident [14-16].

The aim of the present study was to assess as to whether foliar applications of iron was effective in inducing water stress tolerance in sunflower plants.

MATERIALS AND METHODS

This study was conducted on experimental field of Agricultural and Natural Resource Research Center of East Azerbaijan, Iran (37° 58' N, 46° 3' E; 1320 m above sea level) in 2009. Soil consisted of 27% sand, 21% silt and 52% clay. Soil chemical properties are given in Table 1. This experiment was carried out using by a split-split plot with three replications to determination of iron foliar application influence on growth, seed yield and oil yield of two sunflower cultivars (*Helianthus annuus* L. c.v Blizzard and Euroflor) under different irrigation regimes. The main plots were allocated to different irrigation regimes (irrigation after 40, 60 and 75% water depletion based on field capacity), sub plots were sown with sunflower cultivars and finally iron fertilizer (0, 2:10000 and 4:1000 (w: v) from iron sulfate) was introduced to sub-sub plots. After plow, phosphate and potassium fertilizers were incorporated in soil by disk then plots were prepared. Plots were 5 m long and consisted of five rows, 0.6 m apart. Between blocks and main plots, 6 m and 2.4 m alley was kept to eliminate all influence of lateral water movement. Sunflower seeds were disinfected and sown at 3 cm deep (at 25 kg ha^{-1}) on early of May. Plots were thinned to the desired plant population when the seedlings reached the first leaf fully emerged stage. Weeds were removed by hand. Nitrogen fertilizer was incorporated to soil in three stages (one third before sowing one third in stage 4 leaves and one third at flowering stage). In plots which were exposure to low irrigation criteria of water stress was electrical conductivity (Soil Moisture Meter) and gypsum block was used for soil moisture measurement. Water stress was initiated at six leaf stage. Iron foliar application from iron sulfate was carried out at three concentrations by engine backpack sprayer 15 days before and after flowering stage. At the end of growth stage we collected 10 plants from each plot randomly for determination of plant characteristics. Harvested plants were dried by electrical oven at 70°C for 72 h. Oil percentage was obtained using Nuclear Magnetic Resonance (NMR). In addition, Oil yield was calculated by multiplying oil percentage by seed yield.

All data were analyzed from analysis of variance (ANOVA) using the GLM procedure in SAS (SAS Institute, 2002). Duncan's multiple range test (Ref….??) was used to comparison of means at $P<0.05$ probability.

RESULTS AND DISCUSSION

As can be seen from table 2 effect of water stress and different concentration of iron was significant on all traits. In addition, the interaction between water stress × cultivar was significant on stem diameter, while the interaction between water stress and iron was only significant on stem diameter, total dry weight and stem dry weight (Table 2). The results showed that there was no significant different between two sunflower cultivars and two cultivars are exactly the same.

Table 1: Physical and chemical properties of soil collected from site study

Year	Depth (cm)	EC (dSm^{-1})	pH	Organic Carbon (%)	Saturated percentage (%)	N (%)	P (ppm)	K (ppm)	T.N.V (%)
2009	0-30	1.22	7.9	0.46	30.23	0.04	4.7	170	8.33
	30-60	1.45	7.8	0.33	30.43	0.03	2	129	10.43

Table 2: Analysis of variance on growth, yield and yield components of two sunflower cultivars affected by water stress and iron foliar application

S.O.V	d.f	Height	Stem diameter	Dry weight	Leaf area	Leaf dry weight	Stem dry weight	1000 seeds weight	Seed yield	Oil yield
Replication	2	85.40	0.02	6124.68	70.90	442.16	10.90	14.74	576.46	4105.57
Water stress	2	3948.68**	5.93**	1548130.24**	2164262.46**	331154.05**	569349.46**	2823.35**	2044290.13**	547614.35**
Replication ×Water stress	4	193.04	0.01	6105.96	5821.24	3139.47	8118.51	11.18	17814.32	4444.82
Cultivar	1	1.50	0.00	4482.66	3112.96	4835.57	6251.13	5.35	18928.16	1968.07
Water stress × cultivar	4	16.72	0.02*	4900.05	2597.24	1257.24	2836.68	15.24	7415.72	1149.68
Replication × Cultivar (Water stress)	6	24.42	0.00	5463.31	5509.53	2951.74	4605.72	12.77	12158.03	1780.48
Iron	2	2094.01**	0.36**	102461.90**	204583.40**	12212.05*	82205.68**	302.74**	59141.46*	17993.46**
Water stress × Iron	4	46.74	0.03**	22132.76*	13336.07	1008.69	15509.71**	24.01	8799.74	4640.13
Cultivar × Iron	2	9.72	0.00	5718.72	4316.51	1139.46	1840.24	6.74	8892.72	1655.90
Water stress × Cultivar × Iron	4	12.77	0.01	4434.69	9476.96	3658.21	2922.21	7.12	15093.61	2902.35
Error	24	27.43	0.00	5280.84	7105.50	2456.33	3335.76	13.49	12421.45	2851.13
C.V (%)	3.20	2.84	4.03	3.93	8.74	4.70	6.24	4.88	5.59	

* and ** significant at 0.05, 0.01 probability level

Table 3: Main effects of water stress and iron on growth, yield and yield components of two sunflower cultivars

S.O.V	Levels	Height	Stem diameter	Dry weight	Leaf area	Leaf dry weight	Stem dry weight	1000 seeds weight	Seed yield	Oil yield
Water stress	40%	177.44a	3.32a	2035.06a	2515.94a	688.83a	1351.78a	70.61a	2552.78a	1109.17a
	60%	164.38b	3.11b	1900.39b	2076.17b	590.89b	1309.50b	60.11b	2384.00b	986.39b
	75%	147.88c	2.23c	1473.33c	1831.67c	420.78c	1024.78c	45.66c	1903.28c	765.00c
Iron	0	151.27c	2.73c	1724.17c	2028.22c	542.22b	1154.17c	54.38c	2218.61b	922.78b
	2	166.22b	2.92b	1810.06b	2155.56b	564.17ab	1245.89b	59.50b	2289.33ab	951.83ab
	4	172.22a	3.01a	1874.56a	2240.00a	594.11a	1286.00a	62.50a	2332.11a	985.94a

Values within the same column and followed by the same letter are not different at $P < 0.05$ by an ANOVA protected Duncan's Multiple Range Test.

Water stress significantly decreased plant height so that the highest plants were related to those plots which were irrigated after 40% water depletion while the lowest plants were observed from stressed plots, in the other word irrigation after 75% water depletion (Table 3). There are many reports on the basis of decrease of plant height due to water deficit stress [17, 18]. In general, increase of stem length is because of increase in internodes number and length of them however increase of length is more sensitive to water stress than number of nodes. It seems that decrease in height is due to reduction in vegetative growth as a result of water deficit stress.

Stem diameter significantly affected by water stress (Table 2). The most stem diameter was observed when plants were irrigated after 40% water depletion (Table 3). Irrigation after 75% water depletion decreased stem diameter. Decrease in stem diameter on account of water deficit stress can be due to decrease in photosynthesis and assimilates transportation to stems as an important sink in sunflower. Sunflower has with little vegetative growth during flowering stage so water stress can limit plant growth at this time. Similar results have reported by Singh [19]. Water stress decreases vegetative growth period and in spite of decrease dry matter accumulation limits nitrogen uptake.

The results revealed that there was significant differences among different irrigation levels on plant dry weight so that plant dry weight decreased as increasing of water stress intensity (Table 3). This results can be described based on this fact that water stress affects on plant water status and decreases cell division [20]. Effect of water stress is usually accompanied with limited photosynthesis and decrease in photosynthesis leads to decrease in plant dry weight [21].

Leaf area of canopy is an important index related to radiation absorption and determine biological yield. Leaf area depends on genetic background, agronomic practice and climatic conditions. In this study we observed that water stress decrease leaf area dramatically (Table 3). When water stress occurs during earliest stages of sunflower growth, leaf area expansion goes down slowly. By contrast, when water stress occurs during reproductive stages, leaf area would be decreased quickly and leaf aging leads to leaf area reduction [22]. So seed yield would be decreased [23]. On the other water deficit stress decreases cell division and cell elongation. Therefore smaller leaves will be produced [24]. Richie and co-workers have reported that small leaves lead to low seed yield [24].

1000 seeds weight was decreased by increasing water stress intensity. There was significant difference among water stress levels (Table 3). These results are in agreement with those obtained by Unger [25] and Yegappan, *et al.* [26], they reported that the most important factor in increase of seed weight is soil water content during seed filling stage [27]. Water stress affect on available assimilates during seed filling stage and decreases sink capacity and leads to unfilled seeds and low seed weight [28].

Seed yield decreased on account of water deficit stress (Table 3). Decrease in seed weight and increase unfilled seeds were the main reasons for decreasing in seed yield.

Decrease in seed yield due to decrease in yield components especially seed weight has been reported by other researchers previously [25, 26]. Decrease in length of seed filling stage due to water stress is the main factor to decrease seed weight [29]. In this regard *Fereres et al.* [30] showed that water stress decreased seed yield in all sunflower cultivars so that decrease in seed number and seed weight were the main reasons for decrease in final yield. Furthermore, water deficit decreased seed yield via decrease in photosynthesis and seed number per capitulum. Similar results are accessible published by Unger [25].

Comparison of means demonstrated that there were significant differences among water deficit stress levels on oil yield (Table 3). Decrease in oil yield under water deficit stress has been reported by Alza [31].

The results indicated that iron foliar application significantly increased plant height (Table 3). This finding is in agreement with Brown *et al.* [32] who reported that iron improves plant growth. In addition, it has been reported that foliar application of micro nutrients such as iron, increases stem length and also improves dry matter in corn [33].

Iron foliar application increased stem diameter (Table 3). Effect of iron on photosynthesis and photosystems play an important role on plant growth and increase of stem diameter [34].

Leaf dry weight, stem dry weight and total dry weight increased as a result of iron foliar application (Table 3). This increase can be due to increase photosynthesis and growth. Iron deficit stress leads to leaf chlorosis and decrease of dry matter production [32]. It has been reported that iron application in bean plants increased plant growth, biological yield and seed yield [35].

Leaf area increased with iron foliar application (Table 3). Ali *et al.* [36] showed that iron foliar application caused high biological yield, leaf area and seed yield in wheat. 1000 seeds weight was increased because of iron foliar application (Table 3). Obtained results regarding seed weight are in agreement with Bybordi and Malakouti [37] which have reported that zinc increases seed weight while these researches have been reported that iron foliar application had not significant effect on seed weight. Also they have reported that copper and zinc sulfate improved 1000 seeds weight. Increase of seed weight by iron can be due to increase of carbohydrate synthesis [38]. Richie [39] showed that iron increases seed weight. In addition, increase of seed weight in wheat has reported by Yilmaz *et al.* [40].

In case of seed yield and oil yield there was significant difference between application and lack of iron, although there was no significant difference between two iron concentrations. As can be seen from table 3, oil yield was increased on account of the highest concentration of iron. Iron plays an important role in synthesis of chlorophyll and plant growth regulators. Iron improves photosynthesis and assimilates transportation to sinks and finally increased seed yield. Mahmood *et al.* [41] reported that iron application increased wheat yield.

Interaction of water deficit stress and cultivars are shown in Fig. 1. The highest stem diameter was related to Blizzard cultivar when was irrigated after 40% water depletion. By contrast, the lowest stem diameter was obtained from Blizzard cultivar under conditions of high water stress conditions (irrigation after 75% water depletion). According to these results it can be concluded that under normal conditions Blizzard cultivars and under water deficit stress Euroflor cultivar had the highest stem diameter.

The interaction between water stress and iron concentration are given in Fig. 2. The highest stem diameter was observed in those plants which were treated by 4 parts per thousand iron sulfate under normal conditions. On the other hand, water stress and lack of iron led to the thinnest stems. In general, in each irrigation regime iron increased stem diameter. Effect of water stress and iron on total dry weight is shown in Fig. 3. Water deficit stress significantly decreased dry matter production while under normal conditions or mild stress iron foliar application increased dry matter production. Under conditions of severe water deficit stress, iron foliar application had not significant effect on dry matter. The highest dry matter was obtained from those plots which were irrigated after 40% water depletion and treated by 4 parts per thousand iron sulfate.

The interaction between water stress and iron concentration on stem dry weight are given in figure 4. Under normal conditions (irrigation after 40% water depletion) iron foliar application had not significant effect on stem dry weight while under stress conditions iron increased stem dry weight although there was no difference between two iron concentrations.

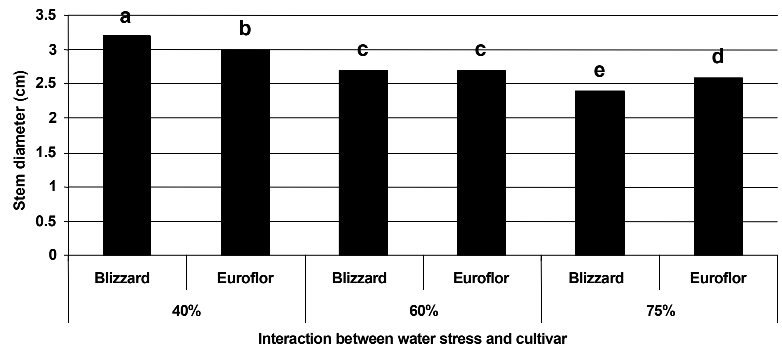

Fig. 1: Interaction between water stress and cultivar on stem diameter. Values with same letter are not different at P < 0.05 by an ANOVA protected Duncan's Multiple Range Test.

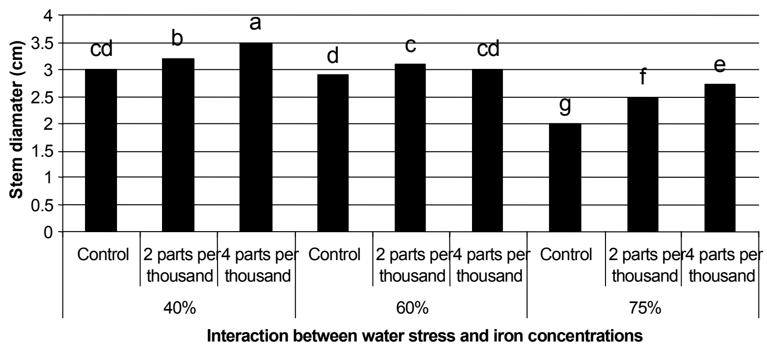

Fig. 2: Interaction between water stress and iron concentrations on stem diameter. Values with same letter are not different at P < 0.05 by an ANOVA protected Duncan's Multiple Range Test.

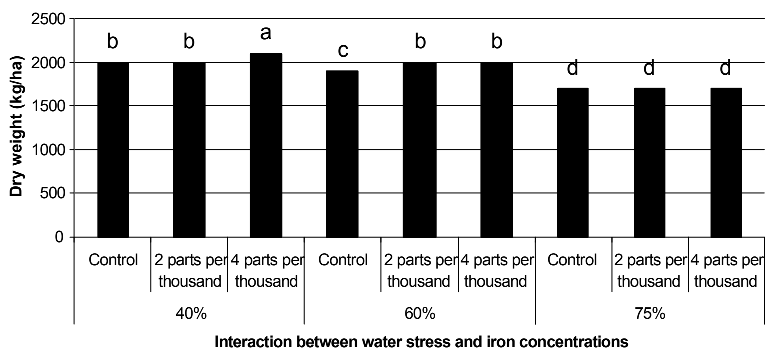

Fig. 3: Interaction between water stress and iron concentrations on dry weight. Values with same letter are not different at P < 0.05 by an ANOVA protected Duncan's Multiple Range Test.

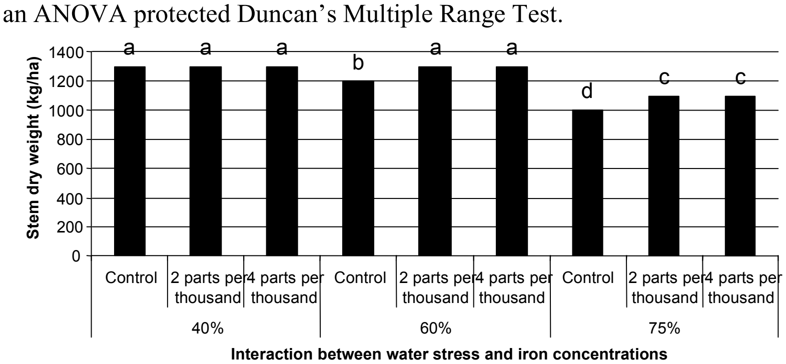

Fig. 4: Interaction between water stress and iron concentrations on stem dry weight. Values with same letter are not different at P < 0.05 by an ANOVA protected Duncan's Multiple Range Test.

CONCLUSION

Iron foliar application under normal and stress conditions played a critical role in seed and oil production so iron foliar application is recommend in sunflower fields especially under water deficit stress.

REFERENCES

1. Turner, L.B., 1991. The effect of water stress on the vegetative growth of white clover (*Trifolium epens* L.): Comparison of long-term water deficit and short-term developing water stress. J. Exp. Bot., 42: 311-316.
2. Ashraf, M. and J.W. O'Leary, 1996. Effect of drought stress on growth, water relations and gas exchange of two lines of sunflower differing in degree of salt tolerance. Int. J. Plant Sci., 157: 729-732.
3. Reisdorph, N.A. and K.1. Koster, 1999. Progressive loss of desiccation tolerance in germinating pea (*Pisum sativum*) seeds. Physiol. Plant, 105: 266-271.
4. Karam, C., 1978. Effect of irrigation intervals on yield components of sunflower. Field Crop Abst., 31: 90, 1977.
5. Reddy, Y.A.N., R.U. Shaoker and K. Virupakshappa, 1995. Studies on sunflower genotypes under moisture stress conditions. 'JAVK, pp: 560-065, Banglore, India.
6. Anwar, M., S. Rehman, S. Khan and Z. Quarishi, 1995. Response of sunflower varieties to different irrigation regimes during Kharif season in Peshawar Valley. Sarhad J. Agric., 11: 273-278.
7. Soriano, M.A., F.J. Villalobos, E. Fereres, F. Orgaz, M. Borin and M. Sattin, 1994. Response of sunflower grain yield to water stress applied during different phonological stages, Abano-Padovo, Italy, pp: 18-22.
8. Volkweiss, S.J., 1991. Fontes e mıtodos de aplicação. In: M.E. FERREIRA and M.C.P. CRUZ, Micronutrientes na agricultura. Piracicaba: POTAFOS; CNPq, pp: 391-412.
9. Cakmak, I., 2002. Plant nutrition research: Priorities to meet human needs for food in sustainable way. Plant Soil, 247: 3-24, Brown, C.L., 1977. Effect of data of final irrigation on yield components of sunflower. Agron., 54: 19-23.
10. Havlin, J.L., J.D. Beaton, S.L. Tisdale and W.L. Nelson, 1999. Soil Fertility and Fertilizers-An Introduction to Nutrient Management 6th Ed. Prentice Hall, New Jersey.
11. Tariq, A., M.A. Gill Rahmatullah and M. Sabir, 2004. Mineral nutrition of fruit trees. Proc. Plant-Nutrition Management for Horticultural Crops under Water-Stress Conditions, Agriculture Research Institute, Sariab, Quetta, pp: 28-33.
12. Bošnjak, D.J. and R. Marinković, 1992. Sunflower requirement for water in the chernozem zone of Yugoslavia. Proc. 13th Int. Sunflower Conference, Piza, Italy, 1: 57-63.
13. Škorić, D., 1992. Achievements and future directions of sunflower breeding. Field Crops Research, 30: 231-270.
14. Jana, P.K., B. Misra and P.K. Kar, 1982. Effect of irrigation at different physiological stages of growth on yield attributes, yield, consumptive use and water use efficiency of sunflower. Indian. Agric., 26: 39-42.
15. Stone, I.R., A.J. Schlegel, R.E. Gwin and A.H. Khan, 1996. Response of corn, grain sorghum and sunflower to irrigation in the High Plains of Kansas. Agric. Water Manag., 30: 251-259.
16. Erdem, T., L. Delibas and A.H. Orta, 2002. Water use characteristics of sunflower (*Helianthus annuus* L.) under deficit irrigation. Pakistan Journal of Biological Sciences, 7: 766-769.
17. Wright, P.R., J.M. Morgan, R.S. Jossop and A. Cass, 1995. Comparative adaptation of canola (*Brassica napus* L.) and Indian mustard (*Brassica Juncea*) to soil water deficit. Field Crop Res., 42: 1-13.
18. Ghobadi, M., 2006. Effect of drought stress and heat stress on morphologic characteristics and yield of spring canola cultivars. PhD dissertation in Agronomy. Shahid Chamran University, Ahvaz, Iran, pp: 219.
19. Singh, S.P., 2007. Drought resistances in the race Durango dry bean landraces and cultivars. Agron. J., 99: 1219-1225.
20. Boyer, J.S. and H.G. Mcpherson, 1976. Physiology of water deficits in cereal grains. In: IRRI (Editors), Climate and Rice. IRRI, Los Banos, Philippines, pp: 321-339.
21. Mwanamwenge, J., S.P. Loss, K.H.M. Siddique and P.S. Cocks, 1999. Effect of water stress during floral initiation, flowering and podding on the growth and yield of faba bean (*Vicia faba* L.). Eur. J. Agron., 11: 1-11.
22. Merrien, A., 1992. Some aspect of sunflower crop physiology. In: proc. of 13th Int. Sunflower Conf., I. Pisa, Italy, pp.481-498.

23. Baldini, M., F. Cecconi, G.P. Vanozzi and A. Benvenuti, 1998. Effect of drought on yield reduction in different sunflower hybrids. Helia, 14: 71-76.
24. Nesmith, D.S. and J.T. Ritchie, 1992. Short-and long-term responses of corn to a preanthesis soil water deficit. Agronomy Journal, 84: 107-113.
25. Unger, P.W., 1992. Time and frequency of irrigation effects on sunflower production and water use. Soil Sci. Soc. Am. J., 46: 1072-1076.
26. Yegappan, T.M., D.M. Paton, C.T. Gates and W.J. Muller, 1982. Water stress in sunflower response if cypselasiz: Ann. Bot., 49: 63-68.
27. Francois, L.E., T.J. Danvan and E.V. Maas, 1984. Salinity effects on seed yield, growth and germination of grain sorghum. Agron. J., 76: 741-744.
28. Li, A., Y. Hou, G.W. Wall, A. Trent, B.A. Kimball and P.J. Pinter, 2000. Free-Air CO_2 enrichment and drought stress effects on grain filling rate and duration in spring wheat. Crop Sci., 40: 1263-1270.
29. Cantagallo, J.E., C.A. Chimenti and A.J. Hall, 1997. Number of seeds per unit area in sunflower correlates well with a photothermal quotient, Crop Sci., 37: 1780-1786.
30. Fereres, E., C. Gimenez and J.M. Fern'andez, 1986. Genetic variability in sunflower cultivars under drought. i. yield relationships. Aust. J. Agric. Res., 37: 573-582.
31. Alza, J.O., 1995. Resistencia a sequia e interaccion genotipo-ambiente engirasol bajo condiciones ambidextries condistinta disponibilidad de agua. Estudios geneticos de estabilidad. Tests de doctorado. Escuela tecnica superior de ingenieros agronomos y de montes. Departamento de genetica. Universidad de Cordoba, espana.
32. Brown, P.H., I. Cakmak and Q. Zhang, 1993. Form and Function of Zinc in plants. In A.D. Robson, (ed), Zinc in Soils and Plants. Kluwer Academic Publishers, Dordrechet.
33. Whitty, E.N. and C.G. Chambliss, 2005. Fertilization of Field and Forage Crops. Nevada State University Publication, pp: 21.
34. Malakoti, M.J. and M.M. Tehrani, 1999. Effects of Micronutriens on the Yield and Quality of Agricultural Products. Tarbiat Modarres University Publications, Tehran, pp: 292. (in Farsi).
35. Singh, A.P., A. Sakal, R.B. Singh and N.S. Hogal, 1993. Seed and oil yield of mustard varieties as affected by zinc application in calcareous soil. Annals of Agricultural Research, 14: 457-462.
36. Ali, S.A.R. Khan, G. Marija, M. Arif, M. Fida and S. Bibi, 2008. Assesment of different crop nutrient management practices for yield improvement. Aust, J. Crop Sci., 2(3): 150-159.
37. Bybordi, A. and M.J. Malakouti, 2003. Effect of iron, manganese, zinc and copper on qualitative and quantitative traits of wheat under salinity conditions. Journal of Soil and Water Science, 17(2): 140-149.
38. Hemantaranjan, A. and D.K. Gray, 1988. Iron and zinc fertilization with reference to the grain quality of *Triticum aestivum* L. J. Plant. Nutr., 11: 1439-1450.
39. Richie, S.W., J.J. Hanway and G.O. Benson, 1992. How a corn plant develops. Special Report No. 48. Iowa State University, pp: 21.
40. Yilmaz, A., I. Cakmak, M. Kalagci, H. Ekiz, B. Tourn, B. Erenaglu and H.J. Braun, 1996. Zinc deficieney as a critical problem in wheat production in central Anatolia. J. Plant and Soil, 180: 165-172.
41. Mahmood, T., R.H. Qureshi, M. Aslam, M. Qadir and M. Ashraf, 1990. Effect of salinity on germination, growth and chemical composition of some members of gramineae pp: 41-2. 3rd. National Congress of Soil Sci, March 20-22, Lahore, Pakistan.