African Journal of Biotechnology Vol. 10(44), pp. 8816-8822, 15 August, 2011
Available online at http://www.academicjournals.org/AJB
DOI: 10.5897/AJB11.854
ISSN 1684–5315 © 2011 Academic Journals

Full Length Research Paper

Effect of sulfur and iron fertilizers on yield, yield components and nutrient uptake in sesame (*Sesamum indicum* L.) under water stress

Mostafa Heidari*, Mohammad Galavi and Maryam Hassani

Department of Agronomy Plant Breeding, University of Zabol, Zabol, Iran.

Accepted 13 June, 2011

To evaluate the effects of sulfur and iron fertilizers on yield, yield components and nutrient uptake in sesame (*Sesamum indicum L.*) under water stress, a field experiment was conducted as split factorial design with three replication at Dezful, Khuzestan, Iran. Two irrigation regimes were used (well-watered and water-limited) as the main plots and subplot consisted of three levels of sulfur (B_1 = 0, B_2 = 100 and B_3 = 200 kg.ha^{-1}) and three foliar application of iron (C_1 = 0, C_2 = 3 and C_3 = 6*1000 concentrations). The results showed that water stress significantly reduced biological yield (10.26%) and number of capsule per plant. Interaction between water stress and combination of iron and sulfur fertilizers had significant effect on grain yield. The highest grain yield was obtained by well water treatment and b_2c_2 fertilizers treatment. Interaction between water stress and combination of iron and sulfur fertilizers had significant effect on nitrogen and iron content in the seeds. The highest iron content of seeds was obtained at water stress treatment and b_1c_2, and highest nitrogen content was at b_1c_2 and b_1c_3 fertilizers treatments.

Key words: Sesame, water stress, sulfur, iron, yield, nutrients content.

INTRODUCTION

Drought is known to limit plant productivity in many regions of the world. Recent studies showed that growth rates of several plants were directly proportional to the availability of water in the soil (Kamel and Loser, 1995). Water deficit is also known to alter a variety of biochemical and physiological processes ranging from photosynthesis to protein synthesis and solute accumulation (Hu and Schmidhalter, 1998). The extent to which photosynthetic capability is maintained during periods of water stress and the ability of rapid recovery of photosynthesis after rewatering may play an important role in plant adaptation to drought environments.

Crop production in arid and semi-arid regions is restricted by soil deficiencies in moisture and plant nutrients. Consequently, adequate levels of irrigation and fertilizers are needed (El-siddig, 1998). High yielding crops need large and regular supply of macro and micro nutrient elements to develop high photosynthetic capacity and maintain the proper elements concentration in the leaves (Lawlor, 1995). The importance of sulfur fertilezation in increasing wheat production and other crops has been well documented, but still it is difficult to determine the quantities to apply under water stress conditions. Sulfur (S) is one of the essential macro elements of plant and is regarded as the fourth key element after N, P and K (Lewandowska and Sirko, 2008).

The effect of micronutrient elements on yield and crop performance has been reported by many investigators. Rehm and Albert (2006) reported that yields were higher for the treatments with micronutrients. In this respect, Singh (2004) reported that foliar sprays of ferrous sulphate were found to be more effective in wheat. Nevertheless, the soil and foliar application of Mn significantly increased the yields, but the rate of soil application of Mn (40 to 50 kg ha^{-1}) is uneconomical than its foliar sprays due to more reversion of soil applied Mn with higher oxide in alkaline soils.

Sesame is considered a drought resistance crop and its cultivation is extended beyond the tropical and subtropical zones to temperate and subtemperate zones of

*Corresponding author. E-mail:Haydari2005@gmail.com. Tel: +98- 9155710972. Fax: +98(0)542-2226762.

Table 1. Some physical and chemical properties of the soil.

Soil property	Value
pH	7.64
EC (ds/m)	0.57
OC (%)	0.62
P (ppm)	5.6
K(ppm)	121
Cu (ppm)	0.9
Fe (ppm)	1.6
Mn (ppm)	4.6
Zn (ppm)	1.2

the world (Ail et al., 2000). The irrigation water regimes affect growth, yield and oil content of sesame plants. In this connection, Hong et al. (1985) indicated that drought stress during vegetative growth reduced seed yield of sesame from 8.5 to 4.3 tha^{-1} and that the main factor in yield reduction was plant height. Iran is a country with semi-arid climate. In most areas, water stress reduces the growth and yield of many crops. The lack of nutrient elements such as iron and sulfur reduce plant growth. The objective of this study was to investigate the effect of iron and sulfur application on growth, yield, yield components and nutrient uptake of sesame (*Sesamum indicum L.*) plants grown under water stress conditions

MATERIALS AND METHODS

In order to evaluate the effects of iron and sulfur application on sesame under water stress, a field experiment in split factorial on the randomized complete block design with three replications was conducted in 2009 to 2010 in Dezful, Khuzestan, Iran (32°22′ N, 48°32′ E; 82 m above sea level). The pH = 7.64, EC = 0.57 ds/m and soil texture of the experimental site were sandy loam. Some physical and chemical properties of the soil are shown in Table 1. Each block consisted of two main plots (for the two irrigation treatments). Two irrigation regimes used were well-watered control (irrigation after 70% field capacity of soil) and water-limited (irrigation after 50% field capacity of soil) irrigation.

Subplot consisted of three levels of sulfur (B_1 = 0, B_2 = 100 and B_3 = 200 $kg.ha^{-1}$) from ammonium sulfate application in soil before sowing) and three foliar application of iron (C_1 = 0, C_2 = 3 and C_3 = 6*1000 concentrations, application at the eight leaf stage). These two treatments were applied as factorial in the subplot. After Fe application, water-limited treatment was laid out. Gotvand cultivar of sesame was used in this study. In the experiment, each subplot was 12 m^2 (4 m width and 3 m length) and consisted of six rows. Plots were fertilized with 150 kg ha^{-1} nitrogen from urea and applied before sowing and after eight leaf stage, 100 kg ha^{-1} phosphorus from super phosphate was applied once before sowing.

At harvest time, sesame plants were collected from each plots and the following characters were determined: plant height (cm), capsules per plant, weight of seed/plant (g), seed and biological yields and harvest index (HI%). Total nitrogen content in grains was determined using the method described by Kjeldahl method. Potassium was determined using Flame Photometer according tothe methods described by Chapman and Pratt (1961). Fe was determined by using Konic Atomic Absorption Spectrophotometer.

Statistical analysis

All data were analyzed using the SAS Institute Inc. Version 6.12 Software. Initially, the data were analyzed in an analysis-of-variance (ANOVA) test to determine significance ($P \leq 0.05$) of the treatment effects. The data were analyzed according to split factorial on the randomized complete block and the differences between averages were tested at 5% significance level in accordance with Duncan multiple comparative method.

RESULTS AND DISCUSSION

Yield and yield components

Analysis of variance revealed a significant effect of water stress on biological yield, number of capsule per plant and harvest index in sesame (Table 2). However, water stress had no significant effect on grain yield, but reduced it (Table 3). Water stress reduced 10.26% biological yield as compared to the control treatment. Fredrick et al. (2001) indicated that water deficit had significant effect on yield of lateral stems of soybean and its yield under normal conditions was higher than that under stress conditions. In this study however, water stress had no significant effect on grain yield in sesame plants, but it had the most effect on yield components, especially biological yield and decreased it to about 10.26% (Table 3). Fredrick et al. (2001) stated that water stress reduced growth and biological yield of soybean.

With iron and sulfur fertilizer, only iron fertilizer had significant effect on grain yield (Table 2). Among the three levels of iron fertilizer, performance increase in yield was observed in C_2 level and increased it to about 22.14% (Table 3). Tekin et al. (2000) conducted a field experiment to determine the effect of soil and foliar application of iron as iron sulphate on the yield of Pistachio nuts. Results revealed that three foliar applications of iron sulphate at 55 ppm was the most effective and soil application at 4 and 6 kg of iron sulphate per tree was also effective in enhancing nuts weight. There was a positive correlation between iron levels and weight of 100-nuts.

Interaction between water stress and combination of iron and sulfur fertilizers had significant effect on grain yield in sesame plants (Table 2). The highest grain yield was obtained at well water treatment and b_2c_2 combination of two fertilizers (Figure 1). Conry (1997) stated that S application from the leaf had a minimum effect on the grain yield of barley. Sulphur based fertilizers decrease the pH of soil and increases the uptake of other plant nutrients. Therefore, the yield increases.

However, iron fertilizer had no significant effect on yield components in sesame plant but sulfur had significant effect on biological yield and number of capsule per plant and increased them. Sulfur fertilizer increased biological yield by 12.91% and number of capsule per plant by 10.62%. This increase was only up to the b_2 for biological yield (Table 3). Withers et al. (1997) reported that

Table 2. Results of analysis of variance (ANOVA) of water stress (W), sulfur (B) and iron (C), and their interaction with gain yield, yield components and nutrients content in sesame.

Independent variable	Dependent variable							
	Grain yield (g m^{-2})	Biological yield (g m^{-2})	Number of capsule per plant	Number of seed per capsule	HI (%)	Nitrogen (%)	Potassium (mg/g DW)	Iron (mg/kg DW)
Block	644.12	306714.24**	891.46	0.907	432.16*	0.0507*	0.142	0.00000313
W	347.57	266985.35**	25654.24**	0.296	96.801*	0.0240	0.462*	0.00048002*
Error$_a$ (Block*W)	2934.68	55744.907	3500.12	0.0185	55.701	0.0497*	0.0674	0.00000257
b	3946.29	175233.85*	6548.57*	0.129	21.281	0.061*	0.197*	0.00069702**
c	29202.57**	57346.074	2258.57	0.074	24.803	0.107**	0.215*	0.00012757*
W*b	301.40	12459.85	17742.12**	0.351	12.261	0.1044**	0.529**	0.00002724
W*c	2966.68	75788.74	11891.24**	0.518	31.721	0.0124	0.624**	0.00049091**
b*c	5015.12*	112098.12*	25473.407**	0.601	52.742*	0.0187	0.072	0.00024057**
W*b*c	5461.35*	393991.57**	10453.12**	0.324	20.490	0.0372*	0.074	0.00049263**
E$_b$	1842.15	33832.69	1841.54	0.317	18.260	0.01259	0.069	0.00004162

W = Irrigation; B = sulfur; C = iron. * P<0.05; ** P<0.01. Numbers represent *F* values at 5% level; ns, not significant.

Table 3. Mean comparisons of the effect of water stress and combination of sulfur and iron fertilizers on gain yield, yield components and nutrients content in sesame.

Parameter	Grain yield (g m^{-2})	Biological yield(g m^{-2})	Number of capsule per plant	Number of seed per capsule	HI (%)	Nitrogen (%)	Potassium (mg/g DW)	Iron (mg/kg DW)
Irrigation								
Well Water	293.41^a	1374.56^a	78.88889^a	360.93^a	22.093^a	3.53370^a	6.64074^b	0.0433333^b
Water stress	288.33^a	1233.93^b	77.04074^b	317.33^b	24.770^a	3.57593^a	6.82593^a	0.0492963^a
Sulfur fertilizer								
B_1	284.94^a	1234.06^b	320.56^b	78.7222^a	23.706^a	3.48778^b	6.65000^b	0.053500^a
B_2	307.72^a	1417.06^a	338.17^{ab}	78.8889^a	24.356^a	3.59444^a	6.71111^{ab}	0.042778^b
B_3	279.94^a	1261.61^b	358.67^a	78.8333^a	22.233^a	3.58222^a	6.83889^a	0.042667^b
Iron fertilizer								
C_1	262.33^b	1332.17^a	338.67^a	78.8889^a	22.500^a	3.49389^b	6.63333^b	0.044778^b
C_2	336.94^a	1239.28^a	350.56^a	78.7778^a	24.750^a	3.52889^b	6.71667^{ab}	0.044778^b
C_3	273.33^b	1341.28^a	328.17^a	78.7778^a	23.044^a	3.64167^a	6.85000^a	0.049389^a

Means with different letters are significantly different at P< 0:05 (Duncan's test). W = Irrigation; B = sulfur; C = iron; Sulfur (B_1 = 0, B_2 = 100 and B_3 = 200 kg.ha^{-1}); Iron (C_1 = 0, C_2 = 3 and C_3 = 6*1000 concentrations).

inorganic S application increased straw yield of cereals by 34%. Our findings are in agreement with the findings of other researchers. The effect of different sulfur applications was statistically significant on number of capsule per plant. The lowest number of capsule per plant was obtained from the control plots, whereas the highest values (10.62%) were obtained from the plots given 200 kg/ha sulfur (Table 3). The sulphur application improved the soil structure and it increased the usefulness of other plant nutrients. Dewal and Pareek (2004) stated that the plant height and the number of seed per spike in wheat were obtained with the application of 40 kg S ha^{-1} application.

Interaction between water stress and combination of iron and sulfur fertilizers had significant effect on biological yield and number of capsule per plant (Table 2). The highest biological yield was obtained at well watered treatment, b_2c_1 and b_3c_3 (Figure 2) and number

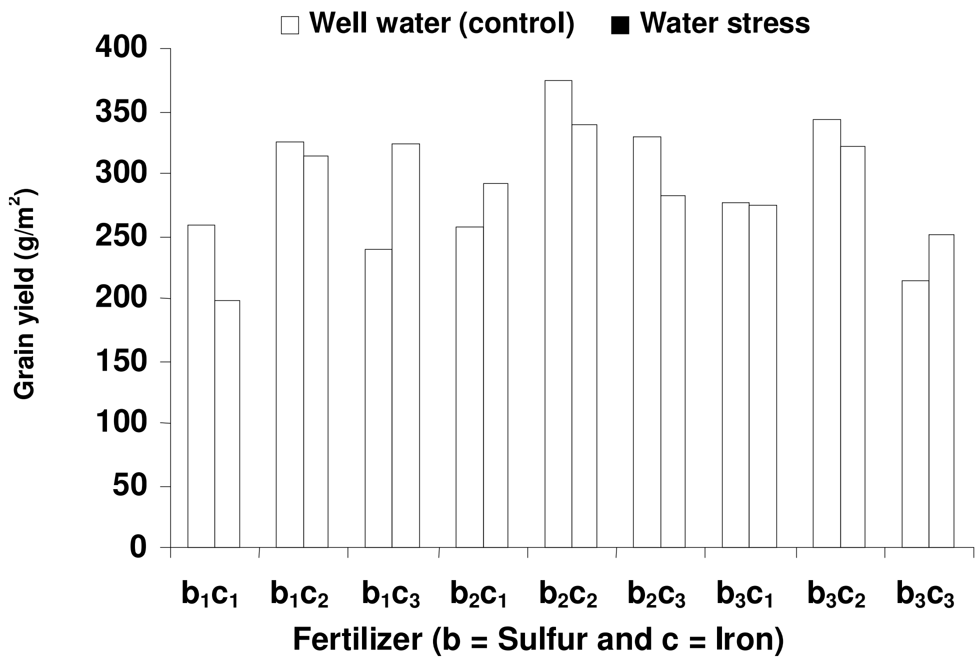

Figure 1. Interaction between water stress and fertilizers on grain yield. Sulfur (B_1 = 0, B_2 = 100 and B_3 = 200 kg ha^{-1}); Iron (C_1 = 0, C_2 = 3 and C_3 = 6*1000 concentrations).

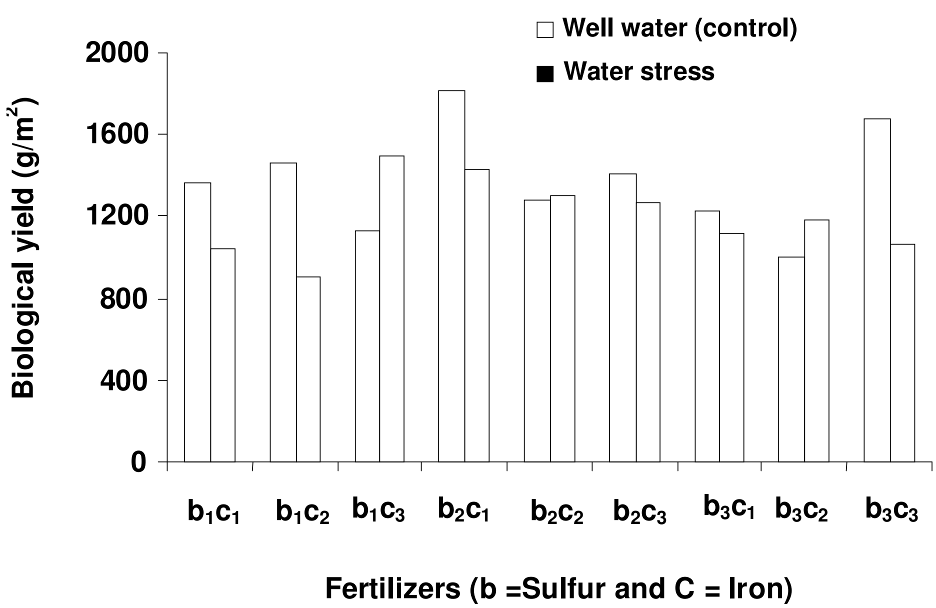

Figure 2. Interaction between water stress and fertilizers on biological yield. Sulfur (B_1 = 0, B_2 = 100 and B_3 = 200 kg ha^{-1}); Iron (C_1 = 0, C_2 = 3 and C_3 = 6*1000 concentrations).

of capsule per plant at b_3c_3 combination of two fertilizers (Figure 3). Salvagiotti and Miralles (2008) showed that S addition increased biomass and grain yield in wheat, showing a positive interaction between N and S, which was reflected in a greater NUE (nitrogen use efficiency).

Nutrient contents in seeds

The results of this study indicate that water stress significantly (*P<0.05*) affected potassium and iron content of the seeds of sesame (Table 2). Water stress increased

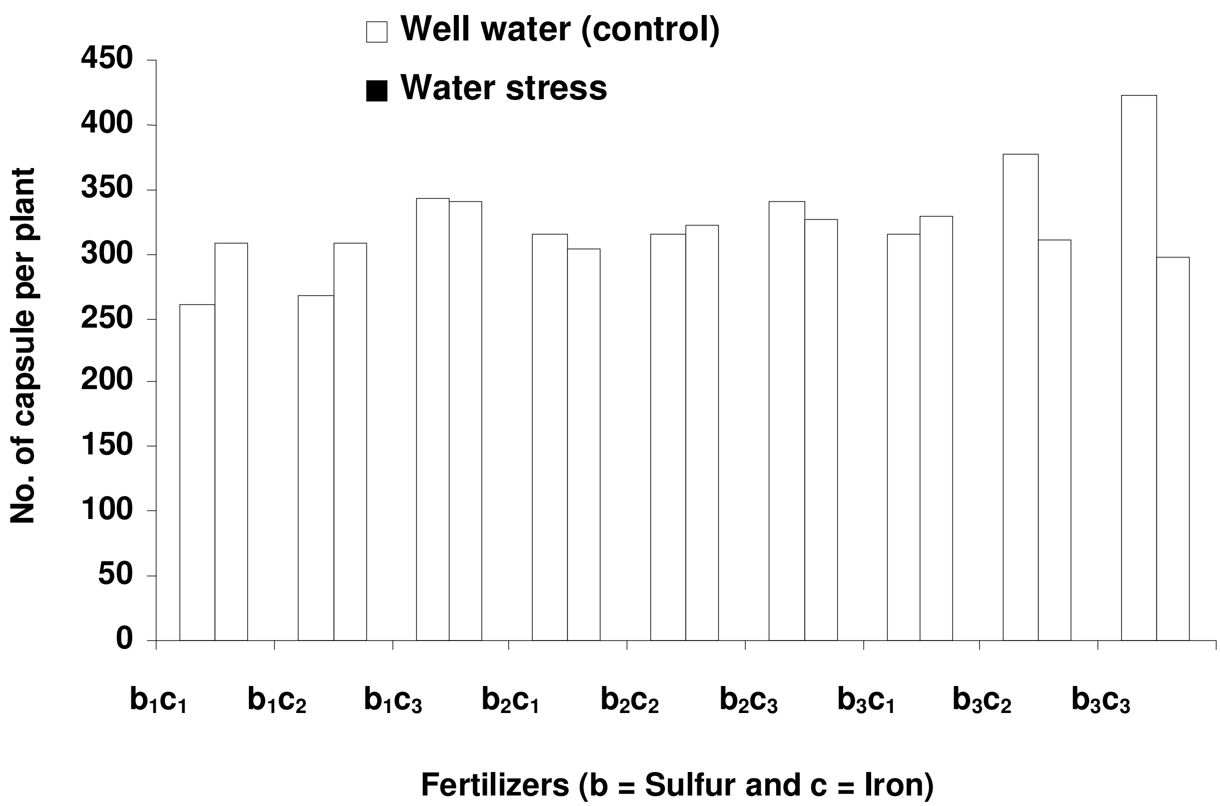

Figure 3. Interaction between water stress and fertilizers and no. of capsule per plant. Sulfur (B_1 = 0, B_2 = 100 and B_3 = 200 kg ha^{-1}); Iron (C_1 = 0, C_2 = 3 and C_3 = 6*1000 concentrations).

Fe and K^+ content of seeds (Table 3). Potassium increases the plant's drought resistance through its functions in stomatal regulation, osmoregulation, energy status, charge balance, protein synthesis and homeostasis (Marschner, 1995). It also maintains turgor pressure and reduces transpiration under drought conditions (Andersen et al., 1992). In plants coping with drought stress, the accumulation of K^+ may be more important than the production of organic solutes during the initial adjustment phase, because osmotic adjustment through ion uptake like K^+ is more energy efficient (Hsiao, 1973).

Sulfur and iron fertilizers had significant effect on potassium, nitrogen and iron content in the seeds of sesame plants (Table 2). Sulfur fertilizer increased potassium and iron content but increased nitrogen in b_2 treatment (Table 3). The iron foliar application increased the amounts of these three elements in the seeds (Table 3). However, S addition in b_2 in the soil showed N increment in seeds of sesame, suggesting that soil S may have been enough to meet the crop N demand at this N uptake level (Salvagiotti and Miralles, 2008). Environmental conditions during the stem elongation period (from terminal spikelet to anthesis in wheat) may affect crop growth and thus, modify the pattern of N uptake (Hocking, 1994).

Interaction between water stress and combination of iron and sulfur fertilizers had significant effect on nitrogen and iron concentration in seeds (Table 2). The highest iron content of seeds was obtained at water stress treatment and b_1c_2 (Figure 4) and nitrogen at b_1c_2 and b_1c_3 combination of the two fertilizers treatments (Figure 5). Application of S containing fertilizer can result to soil acidification and may eventually influence nutrient uptake (Havlin et al., 2007).

Conclusion

From the obtained results, it can be concluded that the use of foliar spraying of iron and application of sulfur can alleviate the harmful effect of water stress on growth, yield components and nutrient elements contents in the seeds of sesame. Interaction between sulfur and iron depends on initial soil fertility status, levels of nutrients applied, test crop and climatic conditions of the region during crop growth period. The results in this study indicated that water stress had significant effect on biological yield and number of capsule per plant and decreased them. However, the highest grain yield was obtained by the well watered treatment but at the water stress condition, application of sulfur and iron (b_2c_2

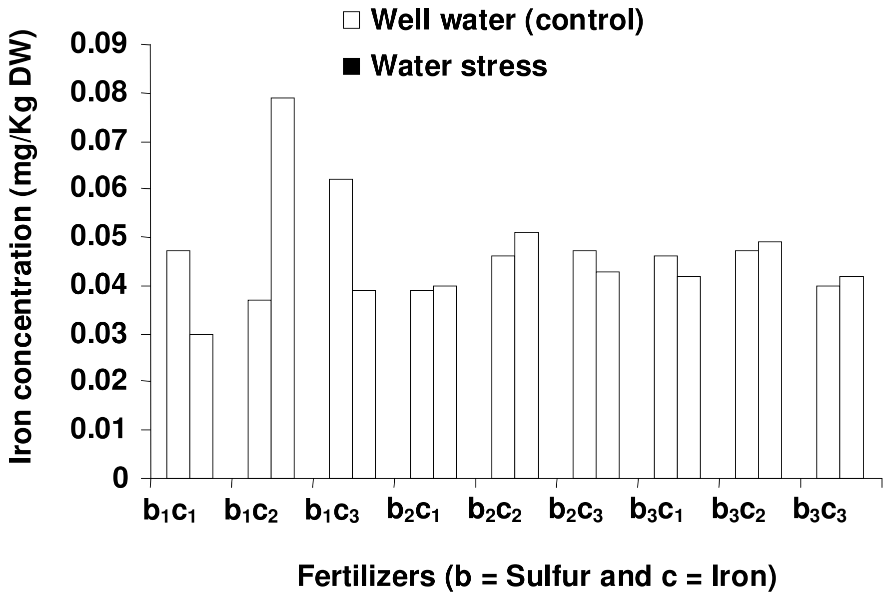

Figure 4. Interaction between water stress and fertilizers on iron concentration in seeds. Sulfur (B_1 = 0, B_2 = 100 and B_3 = 200 kg ha^{-1}); Iron (C_1 = 0, C_2 = 3 and C_3 = 6*1000 concentrations).

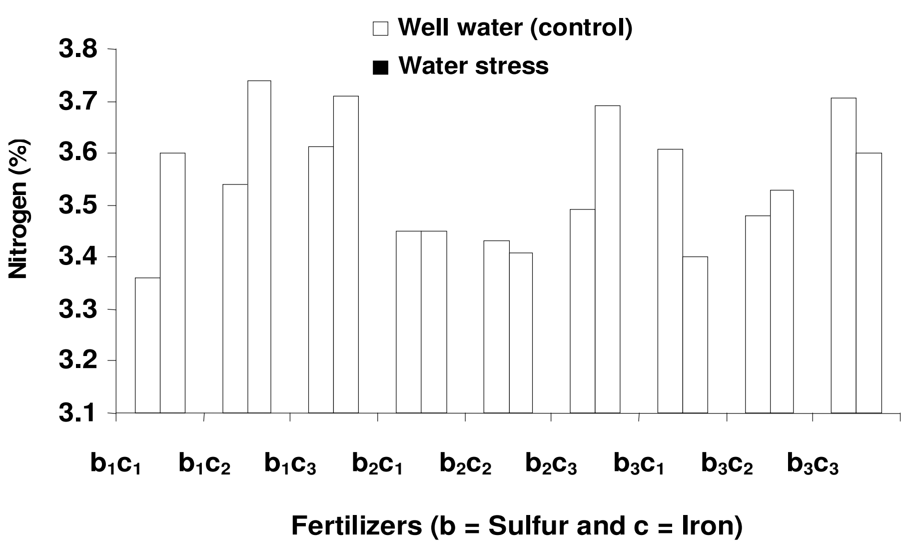

Figure 5. Interaction between water stress and fertilizers on nitrogen content in seeds. Sulfur (B_1 = 0, B_2 = 100 and B_3 = 200 kg ha^{-1}); Iron (C_1 = 0, C_2 = 3 and C_3 = 6*1000 concentrations).

treatment) was more effective on grain yield and yield components, and improved grain yield under water stress.

REFERENCES

Ali A, Kafkafi U, Yamaguchi I, Sugimoto Y, Inanga S (2000). Growth transpiration, root-boron? cytokinins and gibberllins and nutrient compositional changes in sesame exposed to low root-zone temperature under different ratios of nitrate: Ammonium supply. J. Plant Nutr. 23: 123-140

Andersen MN, Jensen CR, Lösch R (1992). The interaction effects of potassium and drought in field-grown barley. 1. Yield, water-use efficiency and growth. Acta. Agriculturae Scandinavica, Section B - Soil Plant Sci. 42: 34-44.

Chapman HO, Pratt PE (1961). Methods of Analysis for Soil, Plants and Water. University of California, Division of Agric. p. 68

Conry MJ (1997). The influence of different nitrogenous fertilizers and

foliar-applied sulphur on the yield, grain nitrogen and screenings of spring malting barley. Proceedings of the Royal Irish Academy, Section B, Biol. Environ. 97(2): 133-138.
Dewal GS, Pareek RG (2004). Effect of phosphorus, sulphur and zinc on growth, yield and nutrient uptake of wheat (*Triticum aestivum*). Indian J. Agron. 49(39): 160-162.
El-Siddig K, Lüdders P, Ebert G, Adiku SGK (1998). Response of Rose Apple (Eugenia jambos L.) to water and nitrogen supply. J. Appl. Bot., 72: 203-206.
Fredrick JR, Camp CR, Bauer PH (2001). Drought-stress effects on branch and mainstem seed yield and yield components of determinate soybean. Crop Sci. 759-763.
Havlin JL, Beaton JD, Tisdale SL, Nelson WL (2007). Soil Fertility and Fertilizers, An Introduction to Nutrient Management, 7th edition, Pearson Education Inc. Singapore, p. 221.
Hocking PJ (1994) Dry-matter production, mineral nutrient concentrations, and nutrient distribution and redistribution in irrigated wheat. J. Plant Nutr. 17: 1289-1308.
Hong Y, Yu JM, Chai KC (1985). Effect of drought stress on upland crops. Research report of the Rural Development Administration Crop, Koera-Republic (C.F. Computure Res). Intl. Agric. Cent. Inform. Serv. 27: 148-155.
Hsiao TC (1973). Plant responses to water stress**.** Ann. Rev. Plant Physiol. 24: 519-570.
Hu Y, Schmidhalter U (1998). Spatial distributions of inorganic ions and carbohydrates contributing to osmotic adjustment in the elongating wheat leaf under saline conditions. Aust. J. Plant Physiol. 25: 591-597.
Kamel A, Loser DM (1995). Contribution of carbohydrates and other solutes to osmotic adjustment in wheat leaves under water stress. J. Plant Physiol. 145: 363-366.
Lawlor DW (1995). The effects of water deficit on photosynthesis In: Environment and plant metabolisim (Smirnoff ed.) Bios. Sci. Publishers. pp. 129-160.
Lewandowska M, Sirko A (2008). Recent advances in understanding plant response to sulfur-deficiency stress. Acta. Biochimica. Polonica, 55: 457-471.
Marschner H (1995). Mineral Nutrition of Higher Plants. Academic Press, London.
Rehm G, Albert S (2006). Micronutrients and Production of Hard Red Spring Wheat. Minnesota Crope News . pp. 1-3.
Salvagiotti F, Miralles DJ (2008). Radiation interception, biomass production and grain yield as affected by the interaction of nitrogen and sulfur fertilization in wheat. Eur. J. Agron. 28(3): 282-290.
Singh MV (2004). IFA International Symposium on Micronurients. 23-25 February 2004.
Tekin H, Arpaci S, Yukceken Y, Cakiri I (2000) Correction of lime chlorosis in Pristachio orchards. Bache, 29(1-3): 19-25.
Withers PJA, Zhao FJ, McGrath SP, Evans EJ, Sinclair AH (1997). Sulphur inputs for optimum yields of cereals. Aspects Appl. Biol. 50: 191-198.