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Barley Grain Mineral Analysis as Affected by Different Fertilizing Systems and by Drought Stress

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ABSTRACT

The effect of different fertilizing systems and drought stress during grain development on grain minerals of barley (*Hordeum vulgare* L.) was studied in field experiments on a clay-loamy soil during 2007 and 2008 growing seasons. The treatments consisted of three irrigation regimes (main plots) of: Non-stressed (NS, normal irrigation continued until the end of plant physiological maturity), Moderate Stress (MS, irrigation ceased from the beginning of flowering to the beginning of grain filling stage and Severe Stress (SS, irrigation ceased from the beginning of flowering stage up to the end of physiological maturity) along with six fertilizing regimes consisting of no fertilizer application (control) (NF), phosphorous and nitrogen Biofertilizers (BF), 100% Chemical fertilizer (NPK) (CF), Vermicompost (VC) 5 t ha^{-1}, 50% Chemical fertilizer (NPK)+50% Vermicompost (2.5 t ha^{-1}) (CV), and 50% Chemical fertilizer (NPK)+ Biofertilizer (CB), assigned to the sub plots. Drought stress significantly increased grain minerals of N, Zn and Mn by 12, 27, and 7% as compared with control (NS), respectively. Average grain nitrogen concentration in chemical fertilizer (CF) treatment was significantly more than those in the other treatments followed by integrated fertilizing systems (CB and CV). Phosphorous concentration in grains produced in BF fertilizer medium was significantly higher than those in other treatments. Grain Fe and Zn concentrations increased through vermicompost application. However, Mn concentration was higher in grains fertilized with chemical fertilizer. It can be concluded that in barley production under water deficit conditions, grain mineral quality could be improved through integrated fertilizer application.

Keywords: Barley, Drought stress, Fertilizer, Grain mineral.

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INTRODUCTION

Barley (*Hordeum vulgare* L.) ranks fifth among field crops in grain production in the world after maize, wheat, rice and soybean (FAO, 2008). In recent years, about two-thirds of barley crop has been used for feed, one-third for malting and about 2% directly for food (Baik and Ullrich, 2008).

In sustainable agriculture, grains are expected to have high nutritional value as well as ability to produce vigorous seedlings to compete weeds, leading to increase in yield. Grain mineral composition influences both nutritional quality and seed vigour. During seed development on the parent plant, nutrient concentration in seed is dependent on soil type, nutrient availability, crop species, weather condition, growing season as well as cultivar (Feil and Fossati, 1995; Rengel *et al.,* 1999).

There is an inconsistency in literature on the quality of organically *vs.* conventionally produced crops because of different

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management practices and environmental conditions. Generally, in organic products, vitamin C, Fe, P, Mg, Zn concentrations were higher as compared with conventional products. However, protein, Mn, K, nitrate and heavy metal concentrations were less (Rengel *et al.,* 1999; Woese *et al.,* 1999; Zhang *et al.,* 2001; Worthington, 2001; Ryan *et al.,* 2004; Salo *et al.,* 2007). Organic and inorganic fertilizers change the crop quality according to their different potential abilities. Inorganic fertilizers are generally more soluble and available at the high plant demand, but organic manure releases minerals slowly which may not be fully available during the critical period of plant demand (Worthington, 2001). Micronutrient concentration rate could be changed through inorganic or organic fertilizer application by the influence on soil pH (Feil *et al.,* 2005) or increasing the organic matter content of the soil (Li *et al.,* 2007). There is a tendency in developed countries to reduce environmental risk and enhance food nutritional value by using more organic fertilizers, while in developing countries; low soil fertility limits the use of organic fertilizers (Kirchmann and Ryan, 2004). Thus it is important to apply the best fertilizing systems to overcome the widespread poverty and achieve the desired international grain food security.

Water is the most precious agricultural resource after land in the water-limited environments. However few studies have dealt with the effect of limited irrigation on the concentration of minerals in grains. Different moisture stress treatments during pre and after anthesis on maize did not affect the mineral concentration in grain (Harder *et al.,* 1982; Feil *et al.,* 2005).

It is assumed that both water and fertilizer (chemical, organic and biofertilizer) can affect mineral concentration in barley grain. To-date, most biofertilizers have been developed and used primarily for supplying N and P to plants, and relatively little is known about their utility for supplying micronutrients.

Nevertheless, microorganisms and organic matter supplements may significantly affect the chemistry of micronutrients in soils, and in some situations they may be manipulated to enhance micronutrient concentration in plants. This study was conducted to fulfill the information about the effects of different fertilizing and irrigation systems on grain mineral concentration in soils with low organic matter content.

MATERIALS AND METHODS

Plant Material

Initial barley (*cv.* Turkman) seed, a spring malting barley seed, used in this experiment for seed production, was provided by the Seed and Plant Breeding Research Institute, Karaj, Iran.

Field Experiments

Field studies were conducted at the Experimental Farm of College of Agronomy and Animal Sciences, University of Tehran, Iran (35° 56’ N and 50° 58’ E with an altitude of 1312 m) during 2006-2007 and 2007-2008 cropping seasons. The soil texture of experimental site was clay loam. Experimental design was a split plot arrangement based on a randomized complete block design with four replications. The seed was sown in 2 by 5 m plots with 1-m alleys in between replications respectively on March 17th, 2007 and December 5th 2007, and at a rate of 300 seed m^{-2}. The treatments consisted of three irrigation regimes (main plots) and six soil fertilizing systems (sub-plots). The irrigation treatments were applied at different phenological stages of barley according to Zadoks scale (1974) consisting of: Non-stressed (NS, normal irrigation until the end of the plant physiological maturity), Moderate Stress (MS, irrigation ceased from the beginning of flowering (Zadoks 65) to the beginning of seed filling stage (Zadoks, 70) and Severe Stress (SS, irrigation ceased from the beginning of flowering stage to the end of the physiological maturity). Fertilizing systems consisted of No Fertilization (control) (NF), phosphorous and Nitrogen Biofertilizers (BF) (Biofertilizer is a complex of different free living nitrogen fixing and phosphorus solubilizing bacteria), 100% Chemical Fertilizer(CF) (NPK) (based on soil chemical analysis), vermicompost (vermicompost, or Vcompost, is a heterogeneous mixture of decomposing vegetable or food waste, bedding materials, and pure vermicast produced during the course of normal vermiculture operations. It is an excellent, nutrient-rich organic fertilizer and soil conditioner (Kelly and Knutzen, 2008) (VC) (applied at 5 t ha^{-1}), 50% chemical fertilizer (NPK)+50% vermicompost (2.5 t ha^{-1}) (CV), and finally 50% chemical fertilizer (NPK)+50% biofertilizer (CB), were assigned to the subplots.

Soil and fertilizer characteristics are presented in Tables 1 and 2. Application of chemical fertilizer was performed based on soil analysis. The levels of N, P, and K applied were 105 kg N ha^{-1}, 32 kg P_2O_5 ha^{-1}, and 170 kg K_2O ha^{-1}, respectively. All P (triple superphosphate), K (K_2SO_4) and organic fertilizers were applied in the soil during land preparation (as base fertilizers), whereas N (urea) was applied in one third at land preparation period (as basal fertilizer) and the rest in the form of topdressing during the tillering and flowering stages, respectively. Normal irrigation was performed at weekly intervals till soil moisture reached 50% of that available at root growth zone. There was no effective rain during the generative growing period (Table 3). At physiological maturity, plants were harvested from the two central rows (omitting the side rows to eliminate the border effects) of each plot. Following harvest the barley ears were threshed by hand and equilibrated to 7-8 percent moisture content (by fresh weight). Samples were ground to pass through a 1-mm screen. Total nitrogen concentration was determined

Table 1. Characteristics of top 20 Cm of soil at experimental sites at initiation of experiment each year.

Year	Parameter										
	Bulk density gr cm^{-3}	Organic carbon %	pH	EC ds m^{-1}	P mg kg^{-1}	N mg kg^{-1}	K mg kg^{-1}	Cu mg kg^{-1}	Mn mg kg^{-1}	Zn mg kg^{-1}	Fe mg kg^{-1}
2007	1.51± 0.049	0.83 ± 0.09	8.5± 0.07	1.112± 0.06	17.4± 12.65	900 ± 35.35	191 ± 462.44	1.39 ± 1.08	17 ± 3.53	0.63 ± 8.26	6.1 ± 4.31
2008	1.58 ± 0.049	0.7 ± 0.09	8.4± 0.07	1.02 ± 0.06	35.3 ± 121.65	850 ± 35.35	845 ± 462.44	2.93 ± 1.08	12 ± 3.53	12.32 ± 8.26	12.2± 4.31

Table 2. Characteristics of applied fertilizers in 2007 and 2008.

Fertilizer	Parameter									
	Organc carbon %	pH	EC dS m^{-1}	P Mg kg^{-1}	N Mg kg^{-1}	K mg kg^{-1}	Cu Mg kg^{-1}	Mn Mg kg^{-1}	Zn mg kg^{-1}	Fe mg kg^{-1}
Chemical fertilizer (CF)				460000	460000	500000				
Vermicompost (VC)	22.2	8.4	6.705	547.5	22950	4729	30.562	156.75	74.925	1666.5
Biofertilizer (BF)	Nitrogen and phosphorous biofertilizers was a complex of different free living nitrogen fixing and phosphorus solubilizing bacteria including *Azosprillium* and *Azetobacter* as nitrogen fixing bacteria and *Bacillus lentus* and *Pseudomonas putida* as phosphorus solubilizing bacteria									

Table 3. Total monthly precipitation, average monthly temperature, average monthly relative humidity and maximum air temperature (T_{max}) for the period 1 October to 31 July in 2007 and 2008, Karaj, Iran.

Month	Precipitation (mm)		Temperature (^{0}C)		Relative humidity (%)		T_{max} (^{0}C)	
	2006-2007	2007-2008	2006-2007	2007-2008	2006-2007	2007-2008	2006-2007	2007-2008
October	71.2	5.5	18.9	17.6	51.0	43	31.0	30.0
November	16.0	33.2	8.4	11.6	61.0	44	22.2	25.0
December	62.9	69.8	1.3	3.6	70.0	64	9.6	16.6
January	45.9	475.2	1.9	-5.7	58.0	76	14.0	6.4
February	44.0	95.0	5.6	1.5	61.2	65.8	14.6	15.0
March	82.2	3.2	7.3	14.7	60.0	34	18.2	37.0
April	100.4	4.1	14.4	17.7	52.0	34	23.6	33.0
May	13.1	0.0	20.3	22.0	45.0	34	22.4	35.0
June	12.6	0.20	24.3	24.6	38.0	36	38.0	37.0
July	6.8	0.1	27.0	27.8	37.0	34	38.4	39.8

using modified Kjeldahl method (Cottenie *et al*., 1982) and phosphorus measured, after dry ashing, through the Vanadad-molybdate method (Page *et al.,* 1982). The concentrations of iron, zinc and magnesium were determined in an air–acetylene through flame atomic absorption spectrometry (AAS) (Shimadzu AA.670, Japan).

Statistical Analysis

Data were statistically analyzed separately for each production year through analysis of variance (ANOVA) using MSTATC (Michigan State Univ., East Lansing, MS, USA) and SAS (SAS Inst., 1990) programs. Homogeneity of error variances was tested using Bartlett's Chi-square. Since value of χ^2 was not significant, so combined analysis of data was performed for two years. The model *Y= year*, *rep (year), irrigation, irrigation*year*, *rep*irrigation (year), fertilizer,fertilizer*year, fertilizer*irrigation, irrigation*fertilizer*year* were denoted for combined analyses within the context of split-plot design. Duncan test ($P< 0.05$) was used to compare means within and among treatments and interactions.

Climatic Conditions

Air temperature and relative humidity measurements indicated that 2008 was a drier year than 2007 (Table 3).

RESULTS

Phosphorus

Irrigation system had significant effect on P concentration in grain in 2007. Phosphorus concentration followed an increasing trend with increase in water stress. Fertilizing systems significantly affected P concentration during both years in which the highest level of P was achieved in BF treatment (Table 4).

Results of combined analysis showed that grain P increased with severity of water stress (Table 5). Phosphorus concentration increased in BF treatment. It was higher in integrated fertilizing (CB and CV) than in chemical fertilizing system. In a combined analysis of variance (2007 and 2008 data), phosphorus concentration across all stress treatments was significantly lower in control and in CF treatments as compared to other fertilizing systems (Figure 1). In full irrigation treatment (NS) the highest P concentration of 0.43% was obtained in BF fertilizing treatment systems.

Nitrogen

Water stress and fertilizing systems had significant effects on grain N% in either year. Nitrogen concentration increased with water stress with the highest N content achieved at SS treatment. CF treatment had the highest N% among fertilizing systems in year 2007 with the integrated systems (CV and CB) having N% as high as that in CF in year 2008 (Table 4).

In combined analysis, changes in N%, in response to water stress, was similar to that in P, though the grain N concentration increased with water stress severity (Table 5).

In combined analysis of variance, as drought stress increased, the grain N concentration followed a significantly increasing trend in all the fertilizing treatments (Figure 1).

Iron

Fe concentration was affected by fertilizing system in 2007. It reached its highest level in CF and CV, respectively. Combined analysis of data over years showed a significantly higher concentration of Fe in CV treatment as compared with other fertilizing systems (Table 5). Combined analysis of variance showed that Fe concentration in the grain did not follow

Table 4. Effects of irrigation and fertilizing treatments on yield and grain minerals concentrations of barley seed in 2007 and 2008.

		P (mg kg^{-1})	N (mg kg^{-1})	Fe (mg kg^{-1})	Zn (mg kg^{-1})	Mn (mg kg^{-1})
2007						
Irrigation system	NS	3630 b	21600 b	51.8 a	51.8 b	20.1 b
	MS	3800 a	21890 b	53.9 a	50.9 b	20.9 ab
	SS	3790 a	22430 a	51.0 a	55.4 a	21.9 a
Fertilizing system	NF	3570 c	21110 cd	48.4 b	52.8 ab	19.7 d
	BF	4050 a	20610 d	50.1 ab	53.0 a	20.3 cd
	VC	3870 ab	21280 c	52.0 ab	53.2 a	21.0 bc
	CV	3670 bc	22760 b	55.0 a	50.9 b	21.8 ab
	CB	3670 bc	21710c	53.2 ab	52.9 a	20.5 cd
	CF	3600 c	24380 a	54.7 a	53.8 a	22.7 a
2008						
Irrigation system	NS	3660 a	20780 b	77.5 a	42.6 c	22.1 b
	MS	3860 a	24430 a	80.6 a	55.6 b	23.0 a
	SS	3780 a	25200 a	79.1 a	73.6 a	23.2 a
Fertilizing system	NF	3870 b	22690 b	76.2 a	53.6 c	22.4 a
	BF	4150 a	22360 b	79.9 a	54.0 c	24.0 a
	VC	3820 b	22450 b	79.4 a	61.3 b	22.1 a
	CV	3680 bc	24510 a	83.7 a	65.4 a	22.4 a
	CB	3670 bc	24200 a	80.1 a	54.6 c	22.9 a
	CF	3420 c	24530 a	75.1 a	54.6 c	22.7 a

Treatments within a column followed by the same letter are not significantly different with the Duncan test at 0.05 level. NS= Normal irrigation until the end of the plant physiological maturity; MS= Ceased irrigation from the beginning of flowering (Zadoks, 65) to the initiation of seed filling stage (Zadoks, 70); SS= ceased irrigation from the initiation of flowering stage; NF= No fertilizing; BF= Phosphatic and nitrogenous biofertilizer, VC= Vermicompost; CV= 50% chemical fertilizer including NPK+50% vermicompost; CB= 50% chemical fertilizer including NPK+50% biofertilizer, CF= 100% chemical fertilizer.

Table 5. Effects of irrigation and fertilizing treatments on grain mineral concentrations of barley seed over two years.

		P (mg kg^{-1})	N (mg kg^{-1})	Fe (mg kg^{-1})	Zn (mg kg^{-1})	Mn (mg kg^{-1})
Year	2007	3740 a	21980 b	52.2 b	52.7 b	21.0 b
	2008	3770 a	23470 a	79.1 a	57.2 a	22.7 a
Irrigation system	NS	3650 b	21190 c	64.7 a	47.2 c	21.1 b
	MS	3830 a	23160 b	67.2 a	53.3 b	21.9 a
	SS	3790 a	23810 a	65.1 a	64.5 a	22.5 a
Fertilizing system	NF	3720 b	21900 c	62.3 b	53.0 b	21.0 c
	BF	4100 a	21490 c	65.0 ab	53.5 b	22.1 ab
	VC	3850 b	21910 c	65.7 ab	57.3 a	21.5 bc
	CV	3680 b	23360 b	69.4 a	58.1 a	22.1 ab
	CB	3680 b	22960 b	66.7 ab	53.7 b	21.7 bc
	CF	3510 c	24450 a	64.9 ab	54.2 b	22.7 a

Treatments within a column followed by the same letter are not significantly different with the Duncan test at 0. 05 level. NS= normal irrigation until the end of the plant physiological maturity. MS= ceased irrigation from the beginning of flowering (Zadoks, 65) to the initiation of seed filling stage (Zadoks, 70). SS= ceased irrigation from the initiation of flowering stage. NF= no fertilizing, BF= phosphatic and nitrogenous biofertilizer, VC=vermicompost,CV=50% chemical fertilizer including NPK+50% vermicompost, CB= 50% chemical fertilizer including NPK + 50% biofertilizer and CF= 100% chemical fertilizer.

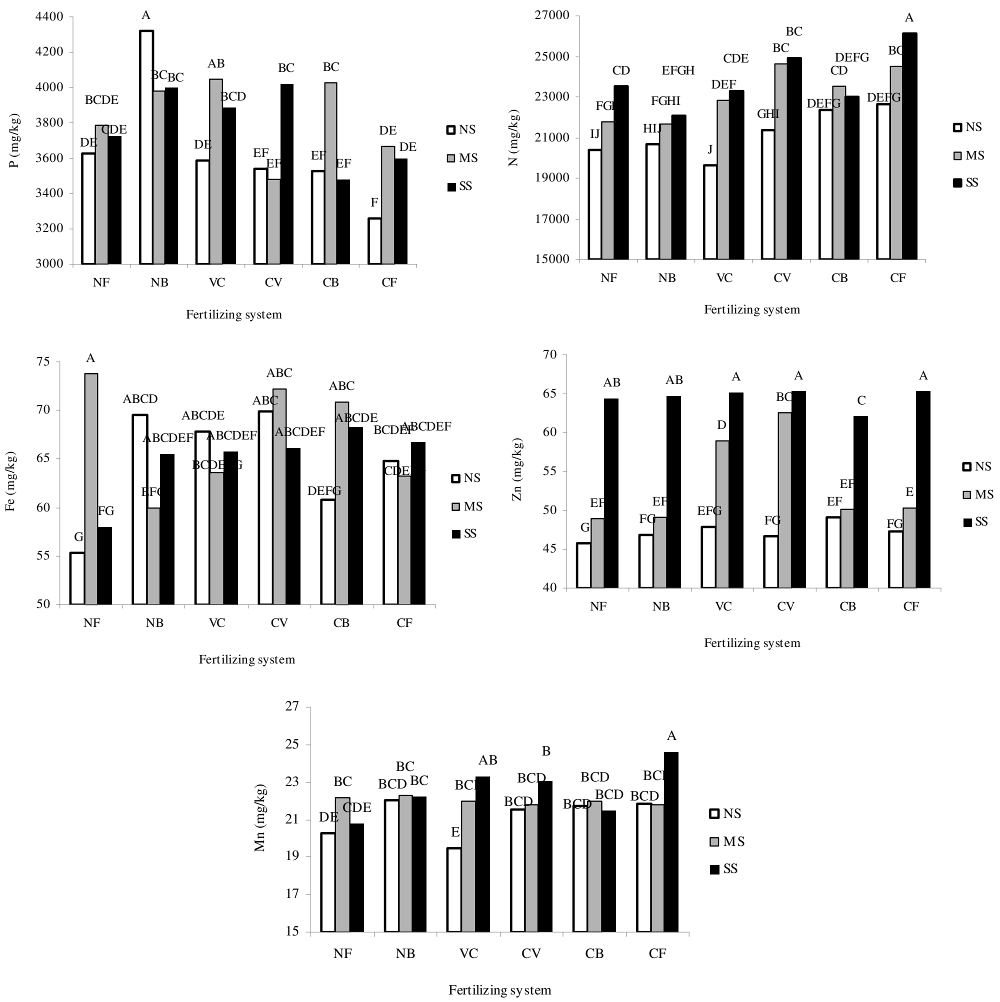

Figure 1. The interaction effect of irrigation and fertilizing systems in combined analysis of variance (2007 and 2008 data) on grain mineral concentrations (P, N, Fe, Zn and Mn). Means with the same letter(s) are not significantly different at *P*< 0.05 level. NS= Normal irrigation until the end of the plant physiological maturity. MS= Ceased irrigation from the beginning of flowering (Zadoks, 65) to the initiation of seed filling stage (Zadoks, 70). SS= Ceased irrigation from the initiation of flowering stage (Zadoks, 65) to the end of the physiological maturity. NF= No fertilizing, NB= Phosphatic and nitrogenous biofertilizer, VC= Vermicompost, CV= 50% chemical fertilizer including NPK+50% vermicompost, CB= 50% chemical fertilizer including NPK+50% biofertilizer and CF= 100% chemical fertilizer.

any special trend at different fertilizing systems and drought stresses (Figure 1).

Zinc

Zinc concentration in grain was significantly affected by water stress in both years. In SS treatment the Zn concentration increased to its highest level in 2007 and 2008 (Tables 4 and 5). Effect of fertilizing systems was also significant on Zn concentration in both years. The lowest level of Zn was observed in CV treatment in 2007, however, the highest level was also observed in the same treatment in 2008.

CV and VC fertilizing treatments caused higher Zn concentration in grain over the two years of experimental period (Table 5).

In combined analysis of variance it was shown that as the drought stress was applied, the grain Zn concentration increased in all fertilizing systems (Figure 1). The trend of Zn increment in vermicompost treatments (comprising of VC and CV fertilizers) was more pronounced. The application of severe drought stress raised the mean Zn concentration to its maximum level of 65 mg kg^{-1}.

Manganese

Irrigation system significantly affected Mn concentration in both years. Manganese concentration increased with water stress intensity, SS treatment creating the highest level of Mn in 2007. The same treatment along with moderate water stress (MS) produced the highest Mn concentration in 2008.

Fertilizing system significantly affected Mn concentration in grain in 2007. CF treatment produced the highest level of Mn concentration followed by CV and VC treatments (Table 4). Combined analysis of variance revealed that a high Mn concentration was observed in SS and MS irrigation treatments as well as in CF fertilizing system (Table 5).

The interaction effect of drought stress treatment and fertilizing systems in NF, CV and CF treatments significantly increased as compared to control (Figure 1).

DISCUSSION

Significant differences in N content as well as in Fe, Zn and Mn concentrations over years could be related to better and longer growing period in 2008 because of earlier planting date and better growing and environmental conditions during this year. The trend towards less concentration of P, N, Zn and Mn in grain in response to normal irrigation revealed the dilution effect of NS treatment for either of the experimental years. Grain mineral concentration decreases in years with high yield (Feil *et al.,* 2005). Mobilization of nutrients from vegetative tissues into the grain can also be a significant source of micronutrients (Rengel *et al.,* 1999; Barczak 2008; Haberle *et al.,* 2008). Plants suffering from nutrient deficiency during reproductive development may totally rely on reserves within the roots, stem and leaves for nutrient concentration in seeds (Grusak *et al.,* 1999).

Higher P concentration in BF among other fertilizing treatments indicated the efficiency of this biofertilizer for insoluble soil P to be used up. This result confirmed the optimum soil P level for efficient utilization of phosphorus by P solubilizing bacteria available in the soil (Table 1). Otherwise application of this biofertilizer could not have any advantage (Kirchmann and Ryan, 2004). In full irrigation treatment (NS) the highest P concentration of 0.43% was obtained in BF fertilizing systems. However, in other fertilizing systems at MS drought stress the level of P was raised as compared to control (NS). This could happen by the decrement of bacteria population as affected by drought stress in BF treatment. At drought conditions, P solubilizing and N fixing bacteria can not demonstrate their potential ability in P and N utilization in the soil (Rehman and Nautiyal 2002). In the same condition at CV and VC treatments, because of the drought stress and the availability of minerals and on the other hand, because of the unsuitable conditions for vegetative growth, the concentration of minerals, especially P, will increase in the plant tissue. Despite application of chemical fertilizer, no significant increase in grain P concentration was observed. This result is supported by results reported by Horst *et al.* (2001).

As drought stress increased, the grain N concentration followed an increasing trend in all the fertilizing treatments (Figure 1). This phenomenon was more obvious in CF treatment where the highest N concentration of 2.6% reached at severe drought stress. The increment of N concentration at drought stress has been reported by many researchers

(Haberle *et al.,* 2008). The steep slope of N increment in vermicompost containing treatments of VC and CV could be because of relatively higher mineralization rate at drought stress conditions which provide more available nitrogen to be absorbed by the plant, causing a more nitrogen concentration in the barley grain. The mineralization rate would be accelerated at drought stress conditions because of higher oxidation rate. Organic fertilizers provide less N to crop as compared to chemical fertilizers because of less N input or inconsistency of N supply with crop demand, thus lower grain N in organic treatments reflected lower N input. This result corresponds to results obtained by Rengel *et al.* (1999); Woese *et al.* (1999); Zhang *et al.* (2001); Worthington (2001); Ryan *et al.* (2004) and Salo *et al.* (2007). Integrated fertilizing can provide more N than organic fertilizer (Montemurro, 2009), though increase in N concentration, is attributed to more N input. Application of chemical fertilizer increased N concentration in comparison to control (No fertilizing) because of more available N in the soil and better efficiency of N absorption in chemical fertilizer treatments. These results are supported by findings reported by Brezink *et al.* (2002).

High levels of Fe and Zn concentrations in vermicompost resulted in more Fe and Zn in VC and CV fertilizing systems (both contained vermicompost). Soil organic matter directly affects Zn and Fe availability (Li *et al.,* 2007). So, higher levels of Fe and Zn concentration can be expected in treatments containing vermicompost. Probably, Fe concentration increases with microbial activities and release of siderophores (Rengel *et al.,* 1999).

Pearson and Rengel (1994) reported that Zn was remobilized from the leaves of wheat and that a greater percentage of Zn was remobilized from leaves in plants with a deficient Zn supply. Also in soybean more than 50% of Zn is remobilized during pod filling (Wood *et al.,* 1986). The high concentration of Zn in treatments under stress (SS and MS) could be resulted from remobilization of Zn to the grain.

Iron has an intermediate mobility within the phloem (Kochian, 1991). According to Miller *et al.* (1993) less than 20% of Fe contained in vegetative tissues was mobilized to the grain. Thus, Fe concentration did not change in different irrigation treatments because of low mobility. In NF, CV and CB treatments Fe concentration in the grain increased at MS and then decreased at SS treatment while at BF, VC and CF treatments no response was observed at different drought stress levels as compared to control (no drought stress). This result can prove genetic control of Fe concentration rather than environmental effects. Other researchers have also reported the genetic control of Fe concentration in plants in previous experiments (Ma *et al.,* 2004).

Ryan *et al.* (2004) described that grain Mn concentrations generally reflect soil exchangeable Mn and pH. It can be concluded that application of superphosphate on soil in CF treatment reduced soil pH and consequently increased Mn availability. The maximum Mn concentration of 24 mg kg^{-1} was achieved at CF treatment when severe drought stress was applied. In other fertilizing systems the fluctuation in Mn concentration was not significant. When the soil pH reaches 7 or less because of environmental conditions, the availability of Mn will increase in soil as well as in plant tissue. Thus application of vermicompost, because of its organic matter content, tends to decrease soil pH and this could explain the results obtained in this experiment.

The quality of protein and the biochemical components of grain developed under water stress condition and fertilizing systems is subject to further investigation in future research. Application of different fertilizing systems will have a long term effect on soil chemical and physical properties. In this research if was not possible to investigate

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this important aspect of environmental effect because of limitations in time and budget.

Water deficit during seed development increased grain protein, P, N and micronutrient concentrations except for Fe (Haberle *et al.,* 2008). It can be concluded that water deficit is able to enhance nutritional value in drought stressed conditions. On the other hand, integrated fertilizing systems, including vermicompost and biofertilizer along with chemical fertilizers have the capacity to provide enough food in sustainable agricultural systems in Iran.

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عناصر معدنی در دانه جو تحت تاثیر نظام های مختلف حاصلخیزی خاک و تنش خشکی

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چکیده

اثر روشهای حاصلخیزی خاک و تنش خشکی (در زمان تشکیل دانه) بر روی خصوصییات شیمیایی و کیفیت غذایی دانه جو در دو سال زراعی ۱۳۸۶ (۲۰۰۷) و (۲۰۰۸) ۱۳۸۷ مورد مطالعه قرار گرفت. تیمار های مورد مطالعه عبارت بودند از سه نظام آبیاری شامل آبیاری هفتگی بر اساس ۵۰٪ تخلیه ذخیره آب قابل دسترس خاک تا پایان دوره رشد فیزیولوژیک گیاه (تیمار شاهد بدون تنش)، قطع آبیاری از مرحله آغاز گلدهی تا آغاز مرحله پر شدن دانه و سپس آبیاری تا پایان دوره رشد فیزیولوژیک گیاه (تنش ملایم خشکی)، و تنش شدید خشکی (قطع آبیاری از مرحله آغاز گلدهی تا پایان دوره رشد فیزیولوژیک گیاه) که به کرتهای اصلی اختصاص یافتند. گروه دوم تیمارها شامل نظامهای مختلف حاصلخیزی خاک: عدم کود دهی (شاهد)، کود زیستی (حاوی باکتریهای تثبیت کننده نیتروژن و تسهیل کننده جذب فسفر)، کود کامل شیمیایی (بر اساس آزمایش خاک)، ورمی کمپوست (به مقدار ۵ تن در هکتار)، کود تلفیقی (شامل ۵۰٪ کود شیمیایی+ ۵۰٪ ورمی کمپوست (۲/۵ تن در هکتار)) و در آخر استفاده از تلفیق کود شیمیایی به مقدار ۵۰٪ + کود زیستی که این تیمارها به کرتهای فرعی اختصاص یافتند. تنش خشکی به طور معنی داری عناصر معدنی دانه شامل نیتروژن، فسفر، روی و منگنز را به ترتیب به مقدار ۱۲، ۴، ۲۷ و ۷ درصد نسبت به تیمار شاهد (بدون تنش) افزایش داد. در تیمار کود شیمیایی میانگین مقدار نیتروژن دانه نسبت به سایر تیمارها به طور معنی داری افزایش یافت. تیمار های کود تلفیقی (کود شیمیایی ۵۰٪ + کود زیستی و ۵۰٪ کود شیمیایی+ ۵۰٪ ورمی کمپوست) به این لحاظ بعد از کود شیمیایی قرار گرفتند. مقدار فسفر در تیمار کود زیستی به طور معنی داری نسبت به سایر تیمارها افزایش یافت. این در حالی است که آهن و روی در تیمار ورمی کمپوست به بالا ترین مقدار خود رسیدند. در شرایط استفاده از کود شیمیایی، فقط عنصر منگنز در دانه های جو نسبت به سایر تیمارها بیشتر بود. می توان چنین نتیجه گرفت که در تولید جو تحت شرایط کم آبیاری، کیفیت عناصر معدنی دانه با کاربرد تلفیقی کود بهبود می یابد.

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