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Application of biological and integrated fertilizers mitigates the adverse effects of drought stress on barley

Saeideh Maleki Farahani[1]* and Mohammad Reza Chaichi[2]

1- Department of Crop Production and Plant Breeding, College of Agricultural Sciences, Shahed University, Islamic Republic of Iran.
2- Department of Crop Production and Plant Breeding, College of Agriculture, University of Tehran, Islamic Republic of Iran.

***Corresponding Author Email**: maleki@shahed.ac.ir

Abstract

Reaching high yield using new soil management operations in areas with scarce water resources and low soil organic matter is a promising necessity in sustainable intensive agriculture. The objective of this research was to study the effect of various combinations of organic and chemical fertilizers and water deficit systems on barley production. The field experiment was set up in two successive growing seasons of 2007 and 2008. Experimental design was a split plot arrangement based on a randomized complete block design with four replications. 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), and consisted of: non-stressed (NS, normal irrigation to the end of physiological maturity), moderate stress (MS, ceased irrigation from the beginning of flowering (Zadoks, 65) to the beginning of the grain filling stage (Zadoks, 70), and severe stress (SS, ceased irrigation from the beginning of flowering stage to the end of physiological maturity). Fertilizing systems consisted of 1. no fertilizer (Control) (NF), 2. phosphorous and nitrogen bio-fertilizers (Bio-fertilizer is a complex of different free living nitrogen fixing and phosphorus solubilizing bacteria) (BF), 3. 100% chemical fertilizer (NPK) (based on soil chemical analysis) (CF), 4. vermicompost (VC) (applied 5 t/ha), 5. 50% chemical fertilizer (NPK)+50% vermicompost (2.5 t/ha) (CV), and finally 6. 50% chemical fertilizer (NPK)+bio-fertilizer (CB), assigned to the sub plots. Seed yield, 1000-grain weight and biomass production were significantly affected by water deficit. Sole application of chemical fertilizer reduced chemical nitrogen fertilizer efficiency, though HI was less than the other fertilizing systems. Organic fertilizers could reduce water stress effects through more water maintenance in the soil. Our results clearly proved the advantage of integrated application of organic and bio-fertilizer along with chemical fertilizer on growth and yield of barley under water deficit and arid conditions.

Keywords: Barely; integrated fertilizing; organic fertilizer; water deficit

Introduction

The increasing growth rate of the world population, coupled with climate change and reduction in production resources, are encouraging stimuli for the promotion of sustainable crop production in current and future farming systems. Sustainable agriculture, especially organic agriculture, is a low input system that implies the efficient use of biological resources. Transition from high input to low input agriculture requires information to solve the problems of the transition period.

Water and nutrients are the most important factors during plant growth and development. Deficit irrigation and use of biological fertilizers are the critical components to crop production in sustainable farming systems (Canbolat *et al.* 2006; Sparks 2009). In such a system, fertilizing with organic fertilizers such as vermicompost, farm-yard manure, nitrogenous bio-fertilizer and phosphatic bio-fertilizers (Phosphate Solubilizing Microorganisms) are noticed. However, there are evidences indicating that the yield in organic farming systems is less than that in conventional production systems, especially in areas with low organic matter in soil (Torstensson *et al.* 2006; Olesen *et al.* 2007; Dawson *et al.* 2007; Ghorbani *et al.* 2008 and Leistrumaitė and Razbadauskienė, 2008). The lower yield in organic production system is attributed to asynchronism of plant need for nutrients especially N and P, and the conversion of nutrients supplied in organic manure to a form available to crops (Kato and Yamagishi, 2011). Although long-term experiments have shown no difference between yield in organic and conventional systems (Kato and Yamagishi, 2011), still the problem of food security for the increasing population during the transition period persists. There is evidence that supports the idea that the chemical fertilizer required to achieve optimum yield levels can be decreased with the application of organic fertilizers (Berecz *et al.* 2005). In some cases the crop yield in integrated chemical and organic fertilizers was even higher than the sole chemical fertilizer treatment (Blaise *et al.* 2006). It appears that managing the fertilizing system during the transition period could provide the possibility of preventing yield losses due to organic production systems.

Since as a consequence of climate change water scarcity is a challenging problem in Iran and other parts of the world, it is necessary to find methods to produce adequate amounts of nationally important crops like wheat and barley.

Barley (*Hordeum vulgare* L.) is widely grown in regions where water deficiency is the most important environmental stress (Baik and Ullrich 2008). Most of the deficit irrigation studies on barley in literature are restricted to water stress after anthesis. Post-anthesis water stress tends to yield reduction by reducing seed per unit area and seed weight (Day *et al.* 1987; Jamieson *et al.* 1995; De Ruiter 1999; Ozturk and Aydin 2004; Szira *et al.* 2008 and Kateri *et al.* 2009), although Farooq *et al.* (2009) have stated that yield reduction intensity depends on timing, duration and the severity of drought stress. Although there are some experiments on different irrigation and fertilizing systems on barley, but there is a lack of information about the interaction effects of water stress along with different fertilizers on barley yield.

Our objective in this experiment was to study the response of barley (Turkman var.) to different fertilizing regimes including organic and chemical fertilizers, and their integrated application under deficit irrigation systems.

Materials and methods

Plant material

The seed of the spring malting cultivated barley Turkman used in this experiment was provided by the Seed and Plant Breeding Research Institute, Karaj, Iran.

Field experiments

Field studies were conducted at the Experimental Farm of the College of Agriculture, University of Tehran, Karaj, Iran (35^o 56' N and 50^o 58' E with an altitude of 1,312 m) during the 2006-2007 and the 2007-2008 cropping seasons. The soil was a clay loam with a pH of 8.4 and 1.02 EC. Karaj has an average annual rainfall of 260 mm and it was about 250 mm for the first year (2007). However, during the second year (2008) the total rainfall was about 380 mm, but the higher precipitation in January and February of 2008 was mostly due to snowfall (Tab 1).

The experimental design was a split plot arrangement based on a randomized complete block design with four replications. The barley was sown in 2m by 5m plots with 3-m alleys between replications on March 17th, 2007 and March 1th, 2008 at a rate of 300 seed m^{-2}, respectively. A buffer of 1m between irrigation treatments in each replication was maintained. 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), and consisted of: non-stressed (NS, normal irrigation to the end of physiological maturity), moderate stress (MS, ceased irrigation from the beginning of flowering (Zadoks, 65) to the beginning of the grain filling stage (Zadoks, 70), and severe stress (SS, ceased irrigation from the beginning of flowering stage to the end of physiological maturity). The irrigation was performed based on 30% depletion of total available soil water (ASW) over 30 cm soil depth. Soil water content measured gravimetrically. Each plot was watered individually through the furrows. Soil moisture content up to the 30 cm of soil depth was measured in all irrigation treatments before re-applying any water to make sure that the soil water potential was around wilting point (-15 bars). The irrigation schedule of limited irrigation treatments at sensitive phenological growth stages of sorghum is presented in Table 2.

Fertilizing systems consisted of 1. no fertilizer (control) (NF), 2. phosphorous and nitrogen bio-fertilizers (Bio-fertilizer is a complex of different free living nitrogen fixing and phosphorus solubilizing bacteria) (BF), 3. 100% chemical fertilizer (NPK) (based on soil chemical analysis) (CF), 4. vermicompost (VC) (applied 5 t/ha), 5. 50% chemical fertilizer (NPK)+50% vermicompost (2.5 t/ha) (CV), and finally 6. 50% chemical fertilizer (NPK)+bio-fertilizer (CB), assigned to the sub plots. Fertilizers' characteristics are presented in Tab 2.

Application of chemical fertilizer was performed based on soil analysis. The amounts 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 to the soil during seedbed preparation (as basal fertilizers), whereas one third of N (urea) was applied during seedbed preparation period (as basal fertilizer) and the rest as topdressing during the tillering and flowering stages, respectively. Normal irrigation was performed at weekly intervals whenever soil moisture reached 50% of available soil water in the root growth zone. There was no effective rain during post-anthesis period (Tab 1).

At physiological maturity, plants were harvested from the two central rows of each plot. After harvest, number of tillers per plant, spikes per plant, grains per spike, grain yield, 1000 grain weight and harvest index (HI) were measured.

Statistical analysis

Data were statistically analyzed separately for each production year by 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 the χ^2 was not significant, a combined analysis of the data was performed for two years. The following model was used for combined analyses within the context of the split-plot design.

Y= year, rep (year), irrigation, irrigation*year, rep*irrigation (year), fertilizer, fertilizer*year, fertilizer*irrigation, irrigation*fertilizer*year

Results and Discussion

Tiller production per plant

Interaction effect of year and fertilizing system affected tiller number significantly (Tab 3). All treatments produced more tiller in the second year than in the first. In first year the integrated and conventional fertilizing systems had superiority in tiller production. However, treatments which were fertilized by biological fertilizers produced more tiller in the second year (Fig 1). The same results were also obtained in 2007. The number of tillers per plant is controlled by temperature during tillering stage, though winter barley produces more tillers compared to spring barley (Royo and Tribo 1997). So the number of tillers in the second year of the experiment could correspond to the lower soil temperature at the early growing stage as compared to the first year.

Spike per plant

Spike per plant significantly increased in biological fertilizer treatments in second year (Fig 2). The results correspond to Kato and Yamagishi (2011) finding that spikes density of wheat varieties were higher in organically managed field than conventional field due to higher pre-anthesis dry matter production. Increase in spike per plant could be the consequence of the increase in number of tillers per plant. In other treatments non significant increase in number of spikes could indicate that some tiller did not produce fertile spikes.

Grain per spike

The number of grain per spike was significantly higher in the second year (Fig 3). The severe drought stress (SS) treatment significantly decreased the number of grain per spike compared to moderate drought stress and normal irrigation during 2007. These results support the results of Szira *et al*. (2008) and Kateri *et al*. (2009). However, no significant effect was observed by drought stress treatments on number of grains per spike in 2008.

The formation of gametes happens before anthesis and during spike formation (Aspinall *et a*l. 1964). Therefore, drought stress had no effect on number of grain per spike in the first year, but in SS the number of hollow grains significantly increased due to the reduction in flower fertilization.

1000-grain weight

Under full irrigation conditions, 1000-grain weight in the second year was more than the first year (Fig 4). It could correspond to more growth rate at the early growth stage because of higher temperature and soil water in the second year, and more assimilates for grain filling. However, drought stress reduced 1000-grain weight in MS and SS treatments in both years. Water stress in MS and SS treatments reduced 1000-grain weight by 8 and 17%, respectively, compared to full irrigation (NS) in 2007. The corresponding figures in 2008 were 20 and 28%.

1000-grain weight of seeds produced under all fertilizing systems followed a decreasing trend as water stress intensity increased. Although in sole application of chemical fertilizer (CF) the decrement was more than the other treatments in both years. Changes in 1000-grain weight are most pronounced after anthesis, because reduction in grain weight is related to the reduction of endosperm cells, amyloplast and assimilates (Nicolas *et al.* 1985). Endospermic cell division and expansion occurs 2 to 3 weeks after anthesis, and water stress in this period ceases cell growth (Gooding *et al.* 2003; Yang. and Zhang 2005). Thus, the induction of post anthesis drought stress in MS and SS treatments caused reduction in grain weight in both years. However, different climatic conditions and higher temperatures during grain filling period (Tab 1), along with drought stress, tended to produce shorter grain filling duration and less 1000-grain weight in 2008. This result also has been confirmed by Gooding *et al.* (2003) who found that drought stress in grain filling period caused less grain filling rate, and higher temperatures at this time pronounced grain weight reduction.

Grain yield

Grain yield was significantly affected by all treatments (Tab 3). It was more in the second year as compared to the first year (Fig 5). This result could be explained by more growth at early growth stage in 2008 as Samarah and Al-Issa (2006) found in their work under normal irrigation conditions. The grain yield was more in CB in the first year, but in the second year it was more in treatments with application of biological fertilizers (NB and VC), though application of chemical fertilizer (CF) had less efficiency in grain production compared to other fertilizing treatments. More precipitation in 2008 could have provided the best conditions for microorganism growth and efficiency. These results are supported by Sahin *et al.* (2004) that found beneficial effects of bacteria depends on environmental conditions, bacteria strain, plant and soil conditions. Miller *et al.* (2009) also found that the effect of organic and inorganic fertilizer on yield of barley is dependent upon site location, soil type or year. Drought stress caused reduction in grain yield in both years. However, the grain yield was less adversely affected by drought stress under integrated fertilizing systems, and in both years the reduction was most pronounced in CF treatment under water stress conditions. These results correspond to Day *et al.* (1987) results who found that nitrogen fertilizer efficiency reduces under water stress condition. Also Berecz *et al.* (2005) described that increasing the application rate of chemical fertilizer reduces the proportion of grain biomass to shoot under water stress conditions. Application of biological fertilizers as vermicompost and microbial fertilizers probably could adjust grain yield reduction through more available water and field capacity enhancement, and supply more nutrient (Creus *et al.* 2004; Wu *et al.* 2006; Koocheki *et al.* 2008; Tabrizi *et al.* 2008) compared to other fertilizing treatmnents. The results suggest that integrated fertilizing systems have the potential to decrease the adverse effects of drought stress on grain yield. These findings could be confirmed by other research works that have found integrated fertilizing has the ability to supply more nitrogen and phosphorus, and reduce carbon loss (Swinnen 1994; Berecz *et al.* 2005; Negassa *et al.* 2005; Blaise *et al.* 2006; Eichler-Lobermann *et al.* 2007; Limon-Ortega *et al.* 2008; Montemurro 2009).

Top-dressing N during the reproductive stage would adjust the yield by aborting small tillers (Kato and Yamagishi (2011). Thus, the application of N as chemical fertilizer at reproductive stage, as done in this research, might increase the yield through more N availability for barley.

Dry matter

Plant dry matter was significantly ($p<0.05$) affected by year (Tab 3). Because of the earlier and more growth, as well as more favorable environmental conditions under normal irrigation (NS), the biomass production was higher in 2008 compared to 2007. Water stress caused biomass reduction in both years (Fig 6). Medium drought stress did not have any significant effect on biomass in 2007. However, because of higher temperature during generative growth, biomass reduced significantly under both MS and SS treatments in 2008.

The application of biological fertilizers (bio-fertilizer and vermicompost) significatly increased the biomass production in 2008 (Fig 7). This result could be explained by the earlier growth in 2008 which was promoted by the high water content of soil, higher temperatures for mineralization of vermicompost, and favorable climatic conditions which provided the proper environment for microorganisms to grow and function more efficiently. Across all fertilizing systems, as the water stress was more severe, the biomass followed a decreasing trend, but the reduction was more pronounced under SS in CF treatment which received only chemical fertilizer (Fig 8). This result followed the same trend as grain yield, however, the reduction in grain yield was more pronunced under SS treatment (40%) compared to biomass (30% reduction). Katerji *et al.* (2009) also found that water stress adversely affects generative parts more severely than vegetative parts.

Harvest Index

The harvest index (HI) in NS treatment during 2008 was higher than 2007 (Fig 9). This result could be attributed to better photosynthesis activity and more assimilates produced, factors which led to more grain production in 2008. However, at water stress treatments due to high temperatures during grain filling period in 2008, the proportion of produced grain to total biomass was reduced.

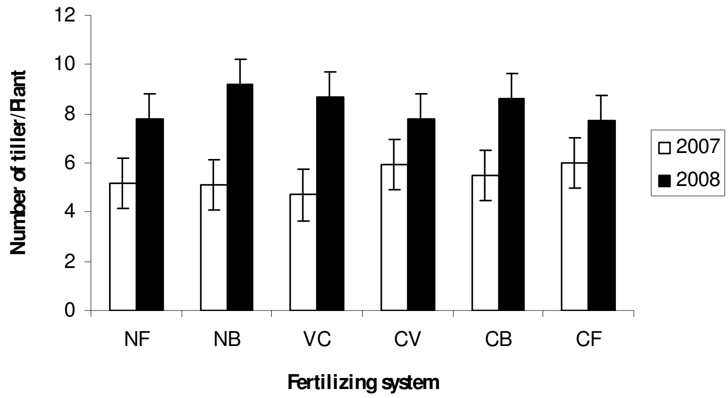

Figure 1. Interaction effect of year and fertilizing system across all irrigation regimes on number of tiller per plant
NF= no fertilizing, NB= phosphate and nitrogenous bio-fertilizer, VC=vermicompost,CV=50% chemical fertilizer including NPK+50% vermicompost, CB= 50% chemical fertilizer including NPK + bio-fertilizer and CF= 100% chemical fertilizer.
Bars indicate ± LSD of means

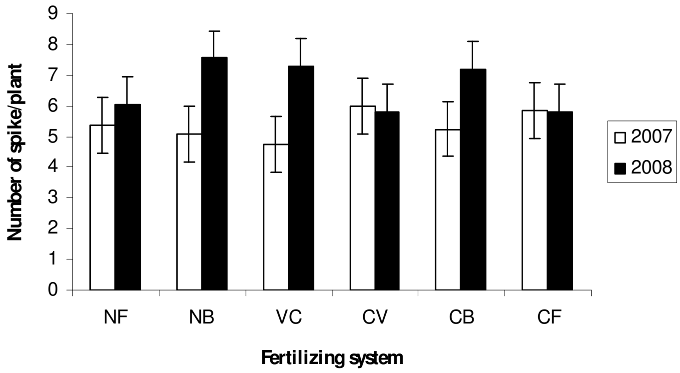

Figure 2. Interaction effect of year and fertilizing system across all irrigation regimes on number of spike per plant
NF= no fertilizing, NB= phosphate and nitrogenous bio-fertilizer, VC=vermicompost,CV=50% chemical fertilizer including NPK+50% vermicompost, CB= 50% chemical fertilizer including NPK + bio-fertilizer and CF= 100% chemical fertilizer.
Bars indicate ± LSD of means

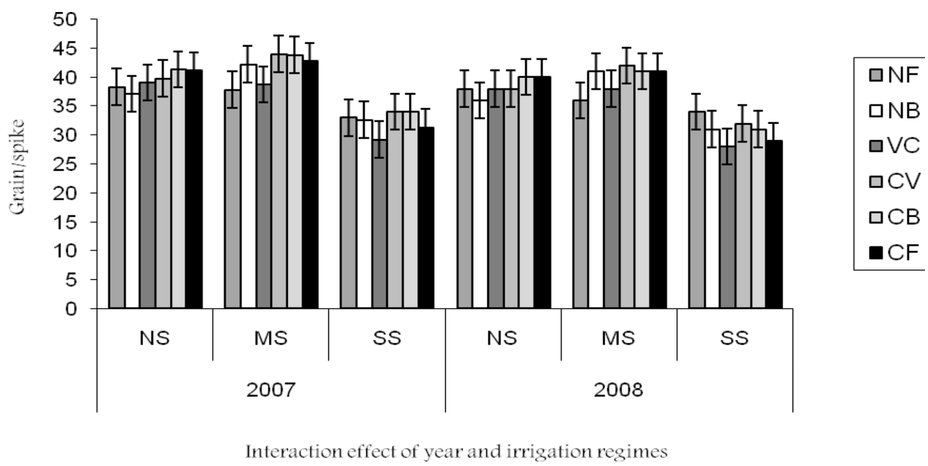

Figure 3. Interaction effect of year, irrigation regimes and fertilizing system on number of grain per spike.
NS (Non- Stress: normal irrigation until the end of the plant physiological maturity)

MS (Medium Stress: ceased irrigation from the beginning of flowering (Zadoks, 65) to the initiation of seed filling stage (Zadoks, 70)
SS (Severe Stress: ceased irrigation from the initiation of flowering stage (Zadoks, 65) to the end of the physiological maturity)
NF= no fertilizing, NB= phosphate and nitrogenous bio-fertilizer, VC=vermicompost,CV=50% chemical fertilizer including NPK+50% vermicompost, CB= 50% chemical fertilizer including NPK + bio-fertilizer and CF= 100% chemical fertilizer.
Bars indicate ± LSD of means

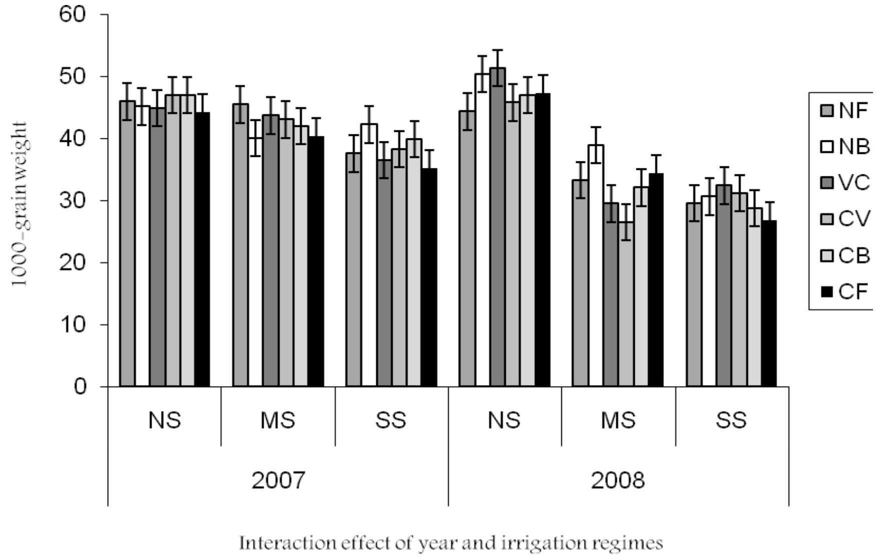

Figure 4. Interaction effect of year, irrigation regimes and fertilizing system on 1000-grain weight
NS (Non- Stress: normal irrigation until the end of the plant physiological maturity)
MS (Medium Stress: ceased irrigation from the beginning of flowering (Zadoks, 65) to the initiation of seed filling stage (Zadoks, 70)
SS (Severe Stress: ceased irrigation from the initiation of flowering stage (Zadoks, 65) to the end of the physiological maturity)
NF= no fertilizing, NB= phosphate and nitrogenous bio-fertilizer, VC=vermicompost,CV=50% chemical fertilizer including NPK+50% vermicompost, CB= 50% chemical fertilizer including NPK + bio-fertilizer and CF= 100% chemical fertilizer.
Bars indicate ± LSD of means

Figure 5. Interaction effect of year, irrigation regimes and fertilizing system on seed yield.
NS (Non- Stress: normal irrigation until the end of the plant physiological maturity)
MS (Medium Stress: ceased irrigation from the beginning of flowering (Zadoks, 65) to the initiation of seed filling stage (Zadoks, 70)

SS (Severe Stress: ceased irrigation from the initiation of flowering stage (Zadoks, 65) to the end of the physiological maturity)
NF= no fertilizing, NB= phosphate and nitrogenous bio-fertilizer, VC=vermicompost,CV=50% chemical fertilizer including NPK+50% vermicompost, CB= 50% chemical fertilizer including NPK + bio-fertilizer and CF= 100% chemical fertilizer.
Bars indicate ± LSD of means

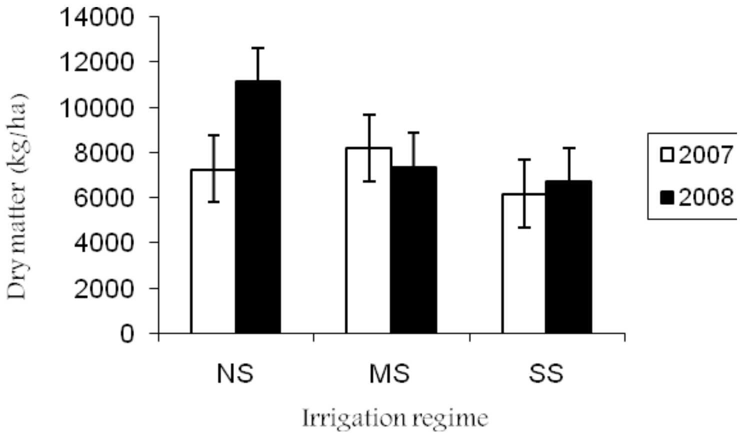

Figure 6. Interaction effect of year and irrigation regimes on biomass.
NS (Non- Stress: normal irrigation until the end of the plant physiological maturity)
MS (Medium Stress: ceased irrigation from the beginning of flowering (Zadoks, 65) to the initiation of seed filling stage (Zadoks, 70)
SS (Severe Stress: ceased irrigation from the initiation of flowering stage (Zadoks, 65) to the end of the physiological maturity)
Bars indicate ± LSD of means

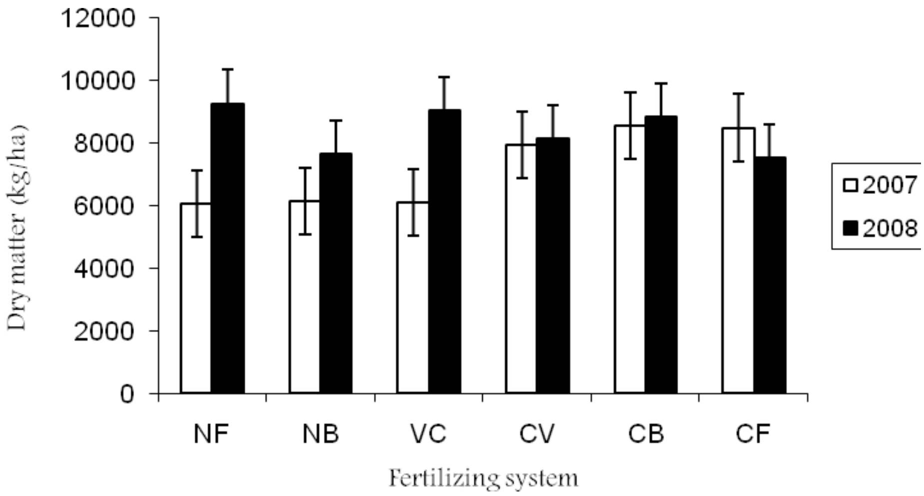

Figure 7. Interaction effect of year and fertilizing system on biomass.
NF= no fertilizing, NB= phosphate and nitrogenous bio-fertilizer, VC=vermicompost,CV=50% chemical fertilizer including NPK+50% vermicompost, CB= 50% chemical fertilizer including NPK + bio-fertilizer and CF= 100% chemical fertilizer.
Bars indicate ± SD of means

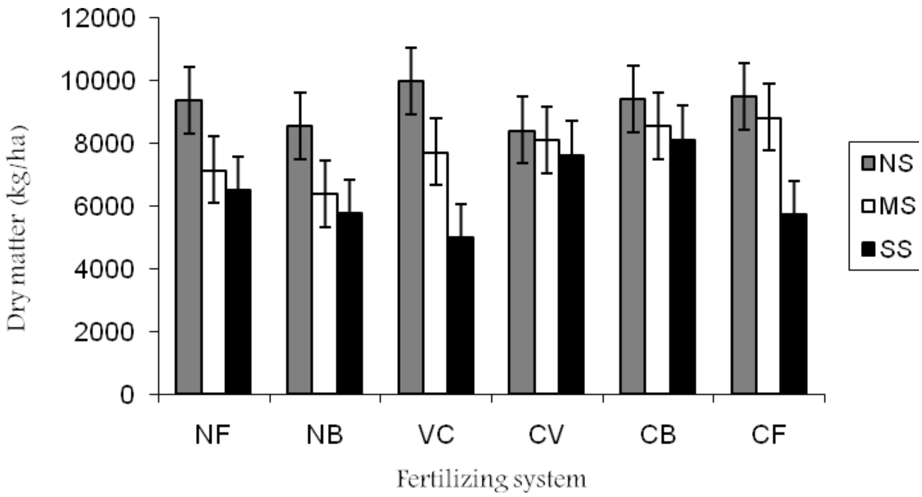

Figure 8. Interaction effect of irrigation regimes and fertilizing system on biomass.
NS (Non- Stress: normal irrigation until the end of the plant physiological maturity)
MS (Medium Stress: ceased irrigation from the beginning of flowering (Zadoks, 65) to the initiation of seed filling stage (Zadoks, 70)
SS (Severe Stress: ceased irrigation from the initiation of flowering stage (Zadoks, 65) to the end of the physiological maturity)
NF= no fertilizing, NB= phosphate and nitrogenous bio-fertilizer, VC=vermicompost,CV=50% chemical fertilizer including NPK+50% vermicompost, CB= 50% chemical fertilizer including NPK + bio-fertilizer and CF= 100% chemical fertilizer.
Bars indicate ± LSD of means

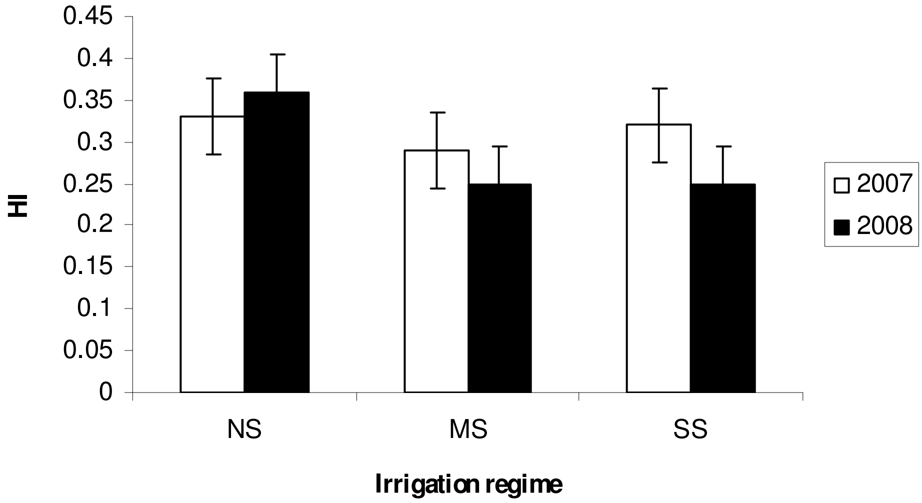

Figure 9. Interaction effect of year and irrigation regimes on HI.
NS (Non- Stress: normal irrigation until the end of the plant physiological maturity)
MS (Medium Stress: ceased irrigation from the beginning of flowering (Zadoks, 65) to the initiation of seed filling stage (Zadoks, 70)
SS (Severe Stress: ceased irrigation from the initiation of flowering stage (Zadoks, 65) to the end of the physiological maturity)
Bars indicate ± LSD of means

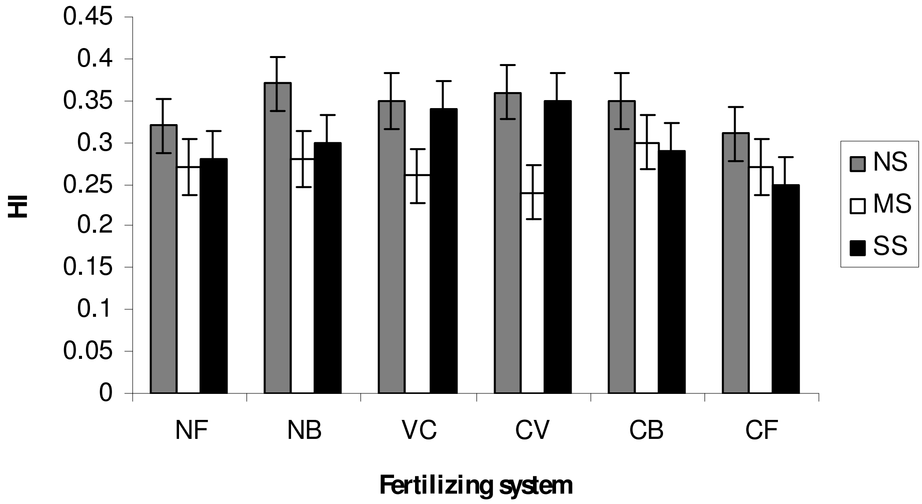

Figure 10. Interaction effect of irrigation regimes and fertilizing system on HI.
NS (Non- Stress: normal irrigation until the end of the plant physiological maturity)
MS (Medium Stress: ceased irrigation from the beginning of flowering (Zadoks, 65) to the initiation of seed filling stage (Zadoks, 70)
SS (Severe Stress: ceased irrigation from the initiation of flowering stage (Zadoks, 65) to the end of the physiological maturity)
NF= no fertilizing, NB= phosphate and nitrogenous bio-fertilizer, VC=vermicompost,CV=50% chemical fertilizer including NPK+50% vermicompost, CB= 50% chemical fertilizer including NPK + bio-fertilizer and CF= 100% chemical fertilizer.
Bars indicate ± LSD of means

Table 1. 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.

Parameter / Fertilizer	Organic Carbon %	pH	EC dS/m	P mg/kg	N mg/kg	K mg/kg	Cu mg/kg	Mn mg/kg	Zn mg/kg	Fe mg/kg
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 2. Characteristics of applied fertilizers in 2007 and 2008.

	Precipitation (mm)		Temperature (^{0}C)		Relative humidity (%)		T_{max} (^{0}C)	
Month	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
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

Table 3. Mean squares for barley yield and yield components as affected by irrigation and fertilizing systems from 2007 to 2008 in Karaj, Iran

Source of variation	DF	Plant height	Tiller	Spikes per plant	Grain per spike	1000 Grain weight	Grain yield	Dry matter	Harvest index
Year *(Y)*	1	580.81 NS	299.57 **	55.75 **	4309.92 **	1069.29 **	4621066.77 *	52.110351.56 *	0.009 NS
Irrigation system (IS)	2	99.27 NS	3.83 NS	12.81 *	198.16 **	2057.31**	21696365.52 **	91190979.52 **	0.06 **
Y × IS	2	75.25 NS	3.88 NS	2.64 NS	330.58 **	510.24 NS	13960188.77 **	68893885.08 **	0.01*
Fertilizing system (FS)	5	120.04 NS	1.42 NS	1.34 NS	8.51 NS	28.83 NS	1052910.92 **	8569197.39 **	0.006 **
Y × FS	5	314.00*	6.10 **	9.34 **	62.30 **	33.22 NS	675229.49 *	16252428.77 **	0.004 NS
IS × FS	10	58.63 NS	2.88 NS	1.13 NS	23.26 NS	16.66 NS	603761.80 *	6377567.20 **	0.005 **
Y × IS × FS	10	18.08 NS	2.74 NS	1.37 NS	23.06 **	34.69 **	643680.46 *	3896331.92 NS	0.003 NS
Coefficient of variation (%)		12.16	21.43	21.31	10.31	10.58	21.97	19.34	15.36

NS: Not Significant, **: Significance level, P<0.01, *: Significance level, P<0.05

Across all fertilizing systems, water stress caused a decreasing trend in HI; however, in treatments which received vermicompost (VC and CV) the reduction in HI did not follow the same trend (Fig 10). It means that probably vermicompost could maintain more water in soil through adding more organic matter. Dawson *et al.* (2008); Courtney and Mullen. (2008); Odlare *et al.* (2008); Manivannan *et al.* (2009) also found the positive effects of vermiciompost on soil water field capacity enhancement. The application of chemical fertilizer caused reduction in HI compared to other fertilizing systems. Reduction of HI is the result of reduced assimilate allocation to grain, which was clearly observed in grain yield reduction in CF treatment. Berecz *et al.* (2005) also indicated that application of high rates of chemical fertilizer tends to limit the grain yield and reduce the grain biomass proportion from total biomass in barley.

Conclusion

The results of this experiment show that the effects of drought stress on growth and yield of barley are significantly influenced by environmental conditions (specially temperature during generative growth). The results also indicate that the adverse effects of drought stress on growth and yield of barely is highly modified by the application of organic fertilizers. Climatic conditions such as precipitation and temprature variation during growing period will also modify the adverse effects of drought stress on barely production.
Although it is not expected of the organic production system to provide adequate food in the early years of transition from conventional production systems, especially under water limitation condition, the results of this study suggest that more attention should be paid to the fertilization of plants with small dozes of chemical fertilizer in order to supply the plant needs at reproductive stage. Otherwise, the yield would be deficient. On the other hand the sole application of chemical fertilizer is unable to guarantee a better yield stability in water deficit areas.

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References

Aspinall D, Nicollas PB, May LH. 1964. The effects of soil moisture stress on the growth of barley. 1. Vegetative development and grain yield. Aust J Agric Res. 15: 729-745.

Baik BK , Ullrich SE. 2008. Barley for food: Characteristics, improvement, and renewed interest. J Cereal Sci. 48: 233-242.

Berecz K, Kismanyoky T, Debreczeni K. 2005. Effect of organic matter recycling in long-term fertilization trials and model pot experiments. Commun Soil Sci Plant Anal. 36: 191-202.

Blaise D, Ravindran CD , Singh JV.2006. Trend and stability analysis to interpret results of long-term effects of application of fertilizers and manure to cotton grown on rainfed vertisols. J Agron Crop Sci. 192: 319

Canbolat MY, Bilen S, Çakmakçı R, Şahin F, Aydın A. 2006. Effect of plant growth-promoting bacteria and soil compaction on barley seedling growth, nutrient uptake, soil properties and rhizosphere microflora. Biol Fert Soils. 42: 350–357.

Cooper J M, Schmidt C, Lueck L, Shotton P , Turnbull C, Leifert C. 2007. Effect of organic, low-input and conventional production systems on yield and diseases in winter barley. 3rd QLIF Congress, Hohenheim, Germany, March 20-23.

Cossani CM, Slafer G, Savin R. 2009. Yield and biomass in wheat and barley under a range of conditions in a Mediterranean site. Field Crops Res. 112: 205–213.

Courtney RG, Mullen GJ. 2008. Soil quality and barley growth as influenced by the land application of two compost types. Bioresource Technol. 99: 2913–2918.

Creus DM, Sueldo RJ, Rolando J, Barassi CA. 2004. Water relations and yield in Azospirillum inoculated wheat exposed to drought in the field. Can J Bot. 82: 273-281.

Dawson J C, Huggins D R, Jones S. 2008. Characterizing nitrogen use efficiency in natural and agricultural ecosystems to improve the performance of cereal crops in low-input and organic agricultural systems. Field Crop Res. 107: 89–101.

Day W, Lawlor D, Day A. 1987. The effect of drought on barley yield and water use in two contrasting years. Irrig Sci. 8:115-130.

De Ruiter JM. 1999. Yield and quality of barley (Hordeum vulgare L. 'Valetta') in response to irrigation and nitrogen fertilization. New Zealand J Crop Horti Sci. 27: 307-317.

Eichler-Lobermann B, Kohne S, Koppen D. 2007. Effect of organic, inorganic and combined organic and inorganic P fertilization on plant P and soil P pools. J Plant Nutr Soil Sci. 170: 623-628.
Farooq M, Wahid A, Kobayashi N, Fujita D, Basra S. 2008. Plant drought stress: effects, mechanisms and management. Agron. Sustain. Dev. 1-28.
Gooding M J, Ellis R H, Shewry P, Schofield J. 2003. Effects of Restricted Water Availability and Increased Temperature on the Grain Filling, Drying and Quality of Winter Wheat. J Cereal Sci. 37: 295-309.
Jamieson P, Martin R, Francis G. 1995. Drought influences on grain yield of barley, wheat, and maize. New Zealand. J Crop Horti Sci. 23: 55-66.
Katerji N, Mastrorilli M,Van Hoorn J, Lahmer F, Hamdy A, Oweis T. 2009. Durum wheat and barley productivity in saline–drought environments. Europ J Agron. 31: 1-9.
Kato Y, Yamagishi J. 2011. Long term effects of organic manure application on the productivity of winter wheat grown in a crop rotation with maize in Japan. Field Crop Res. 120: 387-395.
Koocheki A, Jahan M,Nassiri Mahallati M. 2008. Effects of arbuscular mycorrhizal fungi and free-living nitrogen fixing bacteria on growth characteristics of corn (Zea mays L.) under organic and conventional cropping systems. Proceedings of the Second Scientific Conference of the International Society of Organic Agriculture Research (ISOFAR). Modena, Italy.336-339.
Limon-Ortega A, Govaerts B, Sayre K. 2008. Straw management, crop rotation, and nitrogen source effect on wheat grain yield and nitrogen use efficiency. Europ J Agron. 29: 21–28.
Manivannan S, Balamurugan M, Parthasarathi K, Gunasekaran G ,Ranganathan LS. 2009. Effect of vermicompost on soil fertility and crop productivity - Beans (Phaseolus vulgaris). J Environ Biol. 30: 275-281.
Miller JJ, Beasley B W, Drury CF, Zebarth BJ. 2009. Barley Yield and Nutrient Uptake for Soil Amended with Fresh and Composted Cattle Manure. Agron J. 101:1047–1059.
Montemurro F. 2009. Different Nitrogen Fertilization Sources, Soil Tillage, and Crop Rotations in Winter Wheat: Effect on Yield, Quality, and Nitrogen Utilization. J Plant Nutr. 32: 1-18.
Negassa W, Gebrekidan H, Friesen D. 2005. Integrated use of farmya manure and NP fertilizers for maize on farmers' fields. J Agric Rural Dev Trop Subtro. 106: 131-141.
Nicolas ME, Lambers H, Simpson RJ , Dalling MJ.1985. Effect of drought on metabolism and partitioning of carbon in two wheat varieties differing in drought-tolerance. Ann Bot. 55: 433-444.
Odlare M, Pell M, Svensson K. 2008. Changes in soil chemical and microbiological properties during 4 years of application of various organic residues. Waste Manag. 28: 1246–1253.
Ozturk A, Aydin F. 2004. Effect of water stress at various growth stages on some quality characteristics of winter wheat. J Agron Crop Sci. 190: 93-99.
Royo C,Tribo F.1997. Triticale and barley for grain and for dual-purpose (forage+ grain) in a Mediterranean-type environment. Aust J Agric Res. 48:411-421.
Şahin F, Çakmakçi R, Kantar F. 2004. Sugar beet and barley yields in relation to inoculation with N_2-fixing and phosphate solubilizing bacteria. Plant Soil. 265: 123-129.
Samarah N, Al-Issa TA. 2006. Effect of planting date on grain yield and quality of barley grown under semi-arid Meditarranean conditions. J Food Agric Environ. 4: 222-225.
Sparks R. 2009. Use every drop? Strategis to reduce crop water use. Ppt file
Szira F, Balint AF, Borner A,Galiba G. (2008. Evaluation of drought-related traits and screening methods at different developmental stages in spring barley. J Agron Crop Sci. 194: 334-342.
Swinnen J. 1994. Rhizodeposition and turnover of root-derived organic material in barley and wheat under convetional and integrated management. Agric Eco Environ. 51: 115-128.
Tabrizi L, Koocheki A, Ghorbani R. 2008. Effect of Bio-fertilizers on Agronomic Criteria of Hyssop (Hyssopus officinalis). Proceedings of the Second Scientific Conference of the International Society of Organic Agriculture Research (ISOFAR). 588-591. Modena, Italy
Tambussi EA, Nogues S, Ferrio P, Voltas J, Araus JL. 2005. Does higher yield potential improve barley performance in Meditarranean conditions? A case study. Field Crop Res. 91: 149-160.
Wu QS, Xia RX. 2006. Arbuscular mycorrhizal fungi influence growth, osmotic adjustment and photosynthesis of citrus under well-watered and water stress conditions. J Plant Physiol163: 417-425.
Yang J, Zhang J. 2006. Grain filling of cereals under soil drying. New Phyto. 169: 223-236.
Zadoks JC, Chang TT, Konzak CF. 1974. A Decimal Code for the Growth Stages of Cereals. Weed Res. 14:415-421.