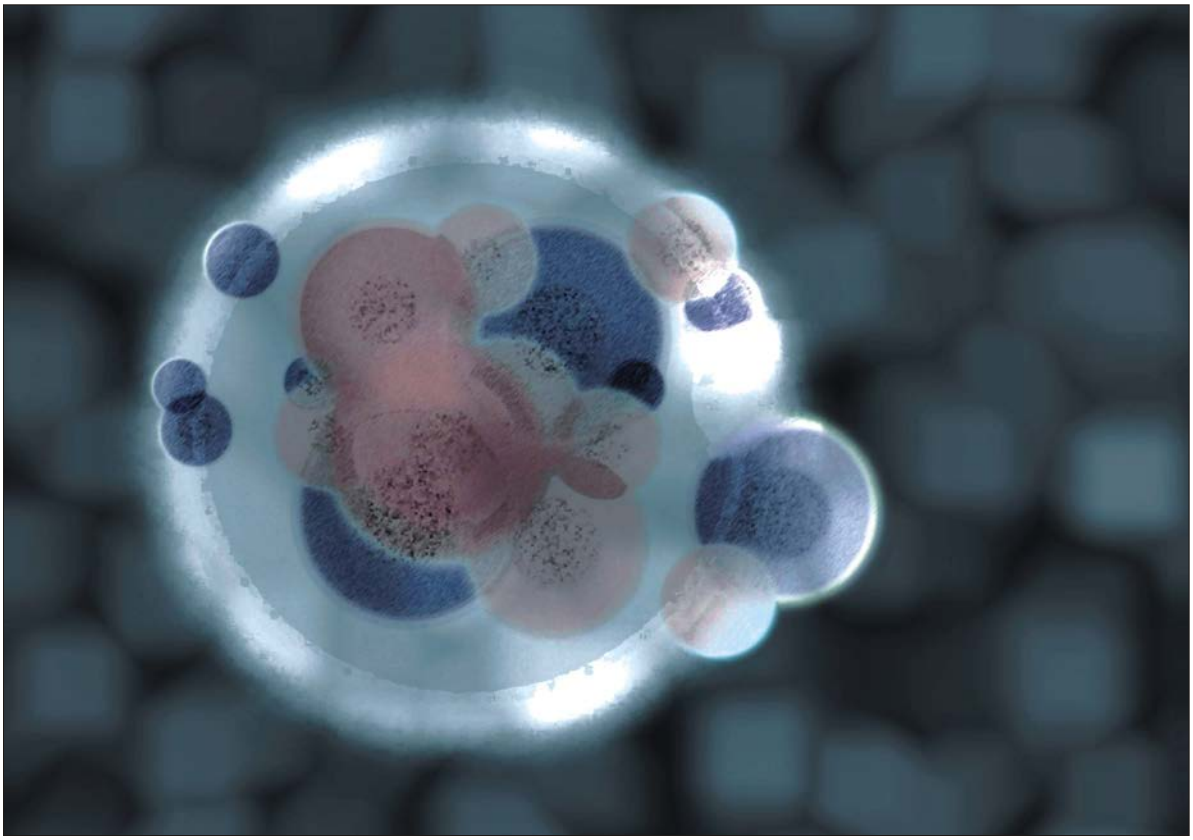

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Effects of Salt Stress on Yield, Yield Components and Carbohydrates Content in Four Hullless Barley (*Hordeum vulgare* L.) Cultivars

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Abstract: In order to evaluate the effects of salinity on some traits of barley, Four hullless barley (*Hordeum vulgare* L.) cultivars (Namely, UH3, UHM7, EHM81-12 and CM67) were grown in research station of Islamic Azad University of Eghlid in Iran, under salt stress in two years (2006 and 2007). Four salinity treatments (1, 5, 10 and 15 dS m^{-1}) were used. The experimental design was a split plot which salt treatments were arranged as main plots and cultivars as subplots, based on a randomized complete block design with three replications. The measured parameters were yield and its components, mono, poly and disaccharides content in flag leaves. Results showed that grain yield, biological yield, harvest index, grain per ear, grain weight and plant height were reduced significantly by salt stress. In all treatments of salinity, CM67 cultivar produced the highest and UH3 cultivar produced the lowest grain and biological yield. In all cultivars, salinity stress decreased starch content but increased sucrose content. In high level of salinity, CM67 cultivar had the highest sucrose content (100.20 mg g^{-1}) in comparison with other cultivars. Thus, this cultivar had the highest tolerance to salt stress than the others and is suitable for cultivation in salinity conditions.

Key words: Hullless barley, salinity, carbohydrates, yield

INTRODUCTION

Barley (*Hordeum vulgare* L.) is potentially useful grain for different purposes. Due to its high soluble fiber content and nutritional significance, it has become a desirable grain for human consumption, especially hullless varieties with high β-glucan content (Bhatty, 1999). There are vast numbers of barley varieties with significant differences in drought and salt stress tolerances. Soil salinization is one of the major factors of the soil degradation. It has reached 19.5% of the irrigated land and 2.1% of the dry-land agriculture existing on the globe. Salinity effects are more conspicuous in arid and semi-arid areas where 25% of the irrigated land is affected by salts (Bhatty, 1999). The increase of salt-affected soils due to poor soil and water management in the irrigated areas, the salinity problem became of great importance for agriculture production in this region (Khosravinejad *et al*., 2009). Soil salinity sometimes is a key factor in determining the ecological distribution of drought-adapted species (Kerepesi and Galiba, 2000). Salinity inhibition of plant growth is the result of osmotic and ionic effects and the different plant species have developed different mechanisms to cope with these effects (Munns, 2002). Plants resort many adaptive strategies in response to abiotic environmental stresses such as salinity. Among them, the accumulation of compatible solutes according to the metabolic responses has drawn much attention (Khosravinejad *et al*., 2009). During the course of salt stress, accumulation of compatible solutes such as amino acids, polyamines and carbohydrates is claimed to be an effective stress tolerance mechanism (Greenway and Munns, 1980).

Carbohydrates changes are of particular importance because of their direct relationship with physiological processes as photosynthesis, translocation and respiration. Among the soluble carbohydrates, sucrose and fructan have potential role in adaptation to stresses (Keles and Öncel, 2004). Sucrose prevents structural changes in soluble proteins and membrane. Glucose acts in respiration and cross-linking with proteins in millard reaction. Fructan is not only a reserve carbohydrate, but also it is considered to play a role key in stress induced metabolic processes (Kerepesi and Galiba, 2000). Salinity cause losses in grain yield (Basu and Nautiyal, 2004). Salinity can reduce number of ear and number of grain per ear (Ozturk and Aydin, 2004). Santamaria *et al*. (1990) demonstrated that severe salinity may cause reduction of grain weight. Negative effect of salinity was found on cell enlargement and growth (James *et al*., 2002). Osmotic

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adjustment is a fundamental adaptive response to plant cell which are exposed to salinity. Organic solutes like carbohydrates can play an important role in balancing osmotic pressure in cytoplasm (Keles and Öncel, 2004). The main objectives of this study are to evaluate the effects of salinity stress on carbohydrates changes and yield of four hullless barley (*Hordeum vulgare* L.) cultivars.

MATERIALS AND METHODS

Experiment was conducted at the Islamic Azad University of Eghlid (34°7´ N, 59°3´ E and asl 2183 m), in Eghlid, Iran, during 2006 and 2007. Soil structure of experimental site's was clay loam which consisted of 60% sand, 37% clay and 3% silt. The meteorological data have been shown in Table 1 (Anonymous, 2008). The experiment was laid out in a split ploton the basis of complete block design with four replications that placed different irrigation water salinity (1, 5, 10 and 15 dS m^{-1}) in the main plots and four hullless barley (*Hordeum vulgare* L.) cultivars (UH3, UHM7, EHM81-12 and CM67) in sub plots. These cultivars are six-rowed, autumn-type and hullless. Each plot consisted of 10 rows spaced at 0.2 and 4 m long. Seeds were sown with 3 cm distance on rows. Saline treatments were started on 20 days after emergence.

The saline solution was made up of NaCl and H_2O which mixed in appropriate tank and concentration required for each salinity level were calculated and added to water (Alshammary *et al*., 2008). Irrigation was carried out when the soil moisture content reach to 90% of FC. Crop management practices were done as required. For yield and yield components measurements, plants were harvested from the 0.25 m^2 area in the middle of each plot. Number of ear $plant^{-1}$, grain ear^{-1} and ear m^{-2} were measured. After oven drying at 75 °C for 48 h, biological and grain dry weight were measured. The protein content was estimated by Kjeldhal method (AOAC, 1984). Water-soluble carbohydrates content at anthesis (Zadoks 65) were quantified in 80% ethanol extracts of stem and leaf tissues according to the method of demonstrated by Keles and Öncel (2004). A sample of 0.1 g of freeze-dried flag leaf was shaken in 10 mL 80% (v/V) ethanol. The insoluble fraction was washed with 5 mL of 80% ethanol. All soluble fractions were centrifuged at 5000 g for 10 min.

The supernatants were collected and stored at 4°C. Glucose was analyzed by reacting 0.5 mL extract with 2.5 mL fleshy prepared anthrone (150 mg anthrone+100 mL H_2SO_4) and placed in a boiling water bath for 5 min (Keles and Öncel, 2004). After cooling the absorbance at 625 nm was determined with spectrophotometer (RF-15LL, Electronical industry Ltd., Iran). For sucrose measurement, samples were hydrolyzed by boiling in 50 g kg^{-1} HCl for 60 min. Sucrose was measured by sucrose kit. For fructan, the sample was placed in water bath at 40°C for 30 min fructan was measured by light absorption at 600 nm (Keles and Öncel, 2004). All obtained data were analyzed by MSTAT-C statistical software and the means were compared by Duncan's Multiple Range Test at the 5% probability level (Steel and Torrie, 1980).

Table 1: Meteorological data of the Eghlid in 2006 and 2007*

Year	Total precipitation (mm)	Mean min. temp. (°C)	Mean max. temp. (°C)	Mean temp. (°C)
2006	403.5	6.4	19.5	12.9
2007	385.6	6.1	22.6	14.3

*Anonymous (2008)

RESULTS AND DISCUSSION

There weren't any significant differences in all measured traits between two experimental years, so the data are average of two years. There were significant differences ($p \leq 0.01$) between cultivars in biological yield, grain yield, harvest index, grain per ear, ear length, grain weight, plant height and protein content (Table 2). Salt stress decreased above traits except protein content. In all treatments, especially in highest level of salinity, CM67 cultivar, showed the highest biological yield (2.547 g $Plant^{-1}$), grain yield (0.493 g $Plant^{-1}$), harvest index (%20.82), grain ear^{-1} (14.27) and ear length (11.91 cm). The lowest grain yield (0.203 g $plant^{-1}$) was obtained In EC = 15 dS m^{-1} by UH3 cultivar (Table 2). In all cultivars, salinity stress decreased starch content but increased sucrose content. There was higher starch content in UH3 cultivar in comparison with others (562.3 mg g^{-1} in EC = 1 dS m^{-1} and 488.3 mg g^{-1} in EC = 15 dS m^{-1}). In CM67 cultivar, sucrose content in EC=15 dS m^{-1} was higher than other cultivars (100.2 mg g^{-1}). Fructan level increased primarily when the salinity level increased to moderate level (10 dS m^{-1}) and it decreased in high salinity (EC = 15 dS m^{-1}). Glucose content was not affected by salinity (Table 3).

Biomass measurement is the best factor for evaluating stress tolerance in crops (Munns *et al*., 2000). Biomass reduction is related to number of tillers, plant height and leaf area reduction (Chen *et al*., 2007). In present experiment, salinity decreased biomass production in all cultivars. Similar result was reported by Razzaque *et al.* (2009). Munns (2002) stated that suppression of plant growth under saline conditions may either be due to decreasing the availability to water or increasing in sodium chloride toxicity associated with increasing salinity. Asch *et al.* (2000) reported that the

Table 2: Effect of salinity on yield and yield components and protein content of four hull-less barley genotypes

Cultivars	S (dS m^{-1})	BY (g $plant^{-1}$)	GY (g $plant^{-1}$)	HI (%)	Grain No. (ear^{-1})	EL (cm)	1000 GW (g)	pH (cm)	Ear No. (m $plant^{-1}$)	P (mg g^{-1})
UH3	1	3.100d	1.320d	42.61a	30.73c	13.63c	42.99a	78.80d	4.40a	70.73e
	5	2.793f	0.813g	29.17d	21.74f	13.35c	37.58c	74.13f	4.00a	72.67d
	10	2.360i	0.470j	20.10f	13.87i	12.26d	35.05cd	68.50i	3.90a	71.05e
	15	2.083j	0.203m	17.87h	9.70k	10.42f	23.65g	63.57j	3.75b	76.49a
UHM7	1	3.702c	1.420c	38.40b	31.80c	14.48b	44.82a	82.4c	4.70a	71.92e
	5	2.963e	0.940f	31.73d	23.77e	14.25bc	38.83b	75.8e	4.30a	73.94d
	10	2.590g	0.610i	24.93e	15.57h	13.87c	39.52b	71.12g	4.00a	74.23c
	15	2.310i	0.336l	14.61i	10.23k	11.94f	29.78f	66.70i	3.20c	74.82c
EHM81-12	1	3.950b	1.530b	38.40b	34.57b	14.78b	40.02b	83.53b	4.28a	72.20d
	5	3.020d	0.976f	33.38c	25.07d	14.54b	38.96b	76.30e	4.11a	73.40d
	10	2.803f	0.680i	24.36e	18.73g	12.89d	36.53c	70.9h	3.90a	73.50d
	15	2.403h	0.400k	16.72h	12.07j	10.95f	31.52e	65.13i	3.30c	76.44a
CM67	1	4.300a	1.690a	42.13a	39.25a	15.10a	43.24a	84.73a	4.10a	73.89d
	5	3.137d	1.037e	33.07c	26.33d	14.72b	39.45b	77.27d	4.00a	75.63ab
	10	2.970e	0.750h	17.00f	20.13f	13.81c	37.68c	72.30g	3.90a	72.71d
	15	2.547g	0.493j	20.82g	14.27i	11.91e	32.73e	66.87i	3.90a	76.86a

Means with the same letter in each column and treatment are not significantly different at probability level of 5% using DMRT. S: Salinity, BY: Biological yield, GY: Grain yield, HI: Harvest index, EL: Ear length, 1000 GW: 1000 Grains weight, PH: Plant height, P: Protein

Table 3: Effect of salinity on carbohydrate content of four hull-less barley genotypes

Cultivars	Salinity (dS m^{-1})	Starch	Sucrose	Glucose	Fructan
		----------(mg g^{-1})----------			
UH3	1	562.3a	61.94e	47.70a	57.67e
	5	508.7e	70.74d	42.43ab	78.00d
	10	497.7ef	84.77c	42.80ab	256.00a
	15	488.3f	94.73b	45.50a	148.00c
UHM7	1	552.0b	64.03e	37.57b	71.67d
	5	494.0ef	68.17de	39.53b	87.67d
	10	395.7g	70.13d	43.70a	210.70b
	15	322.0h	80.77c	43.40a	135.70c
EHM81-12	1	565.7c	66.57de	40.10a	67.33d
	5	465.0f	76.27d	35.07b	101.00cd
	10	367.0g	86.77c	43.53a	201.70b
	15	302.0h	94.80b	41.60a	131.30c
CM67	1	582.0d	61.67de	43.30a	71.00d
	5	508.0e	71.23d	36.33b	114.00cd
	10	469.0f	83.50c	44.90a	251.30a
	15	380.7g	100.20a	42.80a	127.30c

Means with the same letter in each column and treatment are not significantly different at probability level of 5% using DMRT

salt tolerant genotype had the smallest reduction in dry matter and the susceptible genotype had the greatest reduction in dry matter. Grain production potential is determined before anthesis (Pervaiz *et al*., 2002). In this period in current experiment plants grew under saline conditions, so grain yield reduction was possible. These results about crop yield reduction under salinity are consistent with previous findings (Taffouo *et al*., 2009; Sohrabi *et al*., 2008). Salt stress decreased grain number. Sohrabi *et al*. (2008) also reported similar result. Salinity caused reduction in grain weight. This result was the same as results of Sohrabi *et al*. (2008) and Taffouo *et al.* (2009). Grain weight reduction was related to injury in translocation system because of high concentrations of saline ions. However, Zeng *et al*. (2000) reported few differences for grain weight in rice (*Oryza sativa* L.) genotypes in salinity conditions, so severity of salt stress effect on grain weight is related to plant genus and genotype. Salinity increased sucrose content. It was confirmed the results of Hasegawa *et al*. (2000) and Ingram and Bartels (1996). Sucrose is accumulated in many plant tissues in response to environmental stress, including salinity for playing an osmoregulation role and cryoprotection (Balibrea *et al*., 1997). Biochemical studies have shown that plants under salinity stress accumulate number of metabolites, which are termed compatible solutes because they do not interfere with biochemical reactions. These metabolites include carbohydrates, such as manitol, sucrose and raffinose oligosaccharides and nitrogen compounds, such as amino acids and polyamines (Bohnert *et al*., 1995). Khosravinejad *et al*. (2009) found that soluble sugar and proline contents were increased in two barley varieties in response to increased salt concentration, but this increase was different in varieties. Glucose content was not affected by salinity. The result of current study showed that although there wasn't any liable change in glucose and fructan level, total water soluble sugars were increased affected by salinity. Relative constant level of glucose in salinity conditions may relate to the role of glucose in respiration. It means that, released glucose from starch break down, consume in respiratory reactions. This should be experimented.

CONCLUSION

The results of this study showed that grain yield, biological yield, harvest index, grain per ear, grain weight and plant height were reduced significantly by salt stress in four barley cultivars. Also, sucrose content of barley cultivars might play crucial role in the tolerance to the salt stress. Among the cultivars, CM67 had the best accumulate compatible solutes such as sucrose in high levels salinity, so was more tolerance to the salt stress than the others.

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