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Grain quality traits in triticale influenced by field salinity stress

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Abstract

The effect of field salinity stress on the grain quality-related traits in eighteen triticale lines comprising 9 doubled haploid (DH) and 9 corresponding advanced lines (F_8) and two bread wheat cultivars was investigated. Plant materials were grown in two separate experiments under salt stressed and non-stressed conditions in the field in 2008-2009. Grain quality-related traits including dry gluten content, gliadin, glutenin, gliadin/glutenin ratio, sodium dodecyl sulphate (SDS) sedimentation test, protein content, protein yield, carbohydrate content, ash content and test weight were evaluated. Results of combined analysis of variance showed strong influence of environment (saline and normal), genotype and genotype × environment interactions (G × E) on the studied traits with a few exceptions. Protein per hectar was dependent to a greater extent upon grain yield rather than grain protein content under both saline and normal conditions. Grain protein yield decreased when salinity treatment reduced grain yield, even though grain protein percentage increased in both triticale and wheat. Gluten and protein contents were positivly and significantly affected by salinity stress. Salinity casued a decrease of SDS-sedimentation volume and an increase of gliadin/glutenin ratio, both diminishing baking quality. DH line number 2 produced the highest grain protein yield of 1024.1 kg ha^{-1} and 736.0 kg ha^{-1} under non-stress and salt stress conditions, respectively. It is concluded that although salinity enhances quantity of protein, deteriorates quality of protein in the triticale and wheat grains.

Keywords: Gluten**;** protein; salinity; wheat; X. *Triticosecale* Wittmack
Abbreviations : DH- doubled haploid; G × E- genotype × environment; SDS- sodium dodecyl sulphate; TSP- total soluble protein

Introduction

Salinity in soil or water is one of the major stresses that limit plant growth and productivity worldwide. More than 800 million hectares of land throughout the world are salt-affected (including both saline and sodic soil), equating to more than 6% of the world's total land area (FAO, 2011). In Iran based on a recent estimate, 34 Mha or nearly 20 percent of the surface area is salt-affected which includes 25.5 Mha of slightly to moderately and 8.5 Mha of severely salt-affected lands (Cheraghi et al., 2009). The increasing occurrence of dry periods in many regions of the world and the salinity problems associated with irrigated areas frequently result in the consecutive incidence of drought and salinity on cultivated land. Triticale (X. *Triticosecale* Wittmack) is one of the most successful few man-made cereal was synthetized to obtain a cereal that combines unique grain quality of wheat (*Triticum* ssp.) parent with tolerance to abiotic and biotic stresses of rye (*Secale* spp.) parent (Lelley, 2006). Triticale seems to be an interesting alternative to other cereals, particularly bread wheat, in environments where growing conditions are unfavorable or in low-input systems (Erekul and Kohn, 2006). Its baking quality is inferior to wheat because it produces a weaker dough structure. For any genetically complex trait, there is a significant advantage employing highly homozygous genotypes, such as doubled haploid (DH) lines. This is especially indisputable for field salinity experiment, where G × E effects can be very large due to the heterogeneity of salinity in the soil (Arzani, 2008). Protein is the most important component of wheat (*Triticum aestivum* L.) and triticale grains govering end-use quality. Variations in both protein content and composition significantly modify flour quality for bread-making (Weegels et al., 1996; Branlard et al., 2001). Thus, on the one hand, high grain crude protein content is privileged since there is a linear relationship between flour protein content and bread-making quality (Schofield, 1994). On the other hand, higher protein quality signifies better bread-making quality. Although grain protein composition depends primarily on genotype, it is significantly affected by environment factors and their interactions (Zhu and Khan, 2001). Temperature, moisture and soil fertility particularly nitrogen are among the environmental factors that most influences grain protein content in cereal, mainly by affecting grain yield (Rao et al., 1993). Another aspect of milling-quality of importance to millers is test weight, which is highly affected by environmental stress. Since test weight is highly heritable, its positive relationship with grain quality can be used in selection at the early generation of breeding programs (Troccoli et al., 2000). There has been relatively limited investigation regarding the influnces of salinity on grain quality in cereal crops. Previous research in durum wheat showed differntial response of salt tolerant and salt sensitive cultivars to salinity stress in view of grain quality with only salt-tolerant cultivar being significantly affected (Katerji et al., 2005). They found a positive effect of salinity on ash content and SDS sedimentation volume and a negative effect on beta caroten content in grain. On the other hand, Francois et al. (1986) observed a reduction in ash content and protein quality due to salinity by visualizing bread loaf volume with enhanced colour and protein content. The objective of presnt study was to investigate the effects of field salinity stress on

grain quality of triticale DH lines, their corresponding F_8 lines and two bread wheat cultivars ('Roshan' and 'Kavir').

Results and discussion

The total amount of rainfall and its distribution during the three months of evaluation was 21 mm which distributed in 21 April to 21 May (17 mm), 22 May to 21 June (2.3 mm) and 22 June to 22 July (1.7 mm). The total evaporation during the same period was 806 mm. Hence, trial was not affected by rain at the reproductive growth stage of experiment. Salinity significantly influenced all the tested traits, with the exception of glutenin content. Salinity had positive effect on dry gluten content, TSP, protein content and ash content. Although, it changed negatively the rest of traits and led to a decrease in gluten quality by measuring SDS-sedimentation test. The wheat flour quality and grain yield are strongly associated with the genetic factors as well as environmental conditions which considerably affect their expression during grain filling (Souza et al., 2004). In fact, salinity stress as the major environmental variable influenced the rate and duration of wheat grain development and composition in the present study.

Dry gluten content

Results of the combined ANOVA showed the strong influences of environment (saline and normal), genotype and G × E interactions on gluten content (Table 1). Gluten content and composition are the main determinants of the rheological and bread-making properties of wheat flour (Branlard et al., 2001). Salt stress caused an increase in dry gluten content of the genotypes (Table 2). Katerji et al. (2005) observed that the gluten content of two salt sensitive and tolerant durum wheat varieties were not affected by salinity. These authors used irrigated water of three different qualities, fresh water and two saline water (EC= 4.9 and 7 dS m^{-1}). The discriminations of both genotypes and traits for responding to salinity stress were improved in the present study due to a higher salinized water used. 'Roshan' wheat cultivar and F_8 line number 1 exhibited the highest and least gluten content under both conditions, respectively (Table 2). Gluten content mean values of triticale lines and wheat cultivars differ significantly under both environmental conditions with wheat cultivars being significantly superior under both environmental conditions (Table 2). This result was reasonable due to the lacking D genome and possesing of R genome in triticale.

Flour gliadin and glutenin contents

Glutenin content was not affected by salinity in the present study. On the other hand, gliadin content was significantly influenced by salinity (Table 1). Under both conditions, genotypic effect was significant for flour gliadin and glutenin contents. Mean of gliadine ranged from 0.243 for DH line number 1 to 0.393 for DH line number 8 under non-stressed experiment and from 0.287 for DH line number 7 to 0.453 for DH line number 8 under salt stressed experiment (Table 2). There was a significant difference between triticale lines and wheat cultivars for their means of gliadin and glutenin content with wheat cultivars being significantly superior (Table 2). Dough properties have been related to gliadin/glutenin balance (Peña et al., 2005). In our study, the gliadin content increased under salt-stress conditions, but the glutenin was not affected by salinity, resulting in an increased ratio of gliadin to glutenin (Tables 2 and 3). The results of

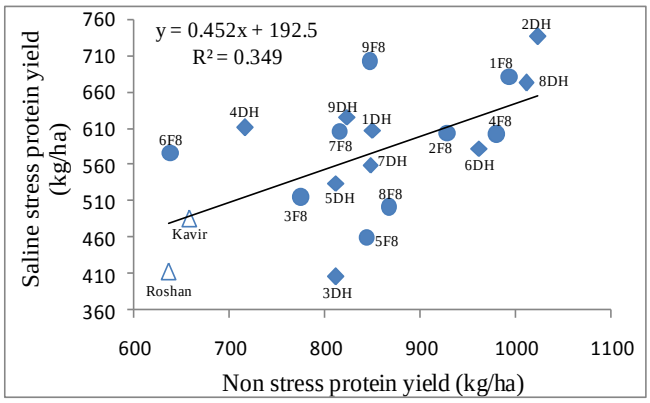

Fig 1. Relationship between protein produced under non-stressed and salt stressed field conditions**.**

present study suggest that salinity stress increased the synthesis of monomeric proteins (gliadins) at the expense of the polymeric proteins (glutenins), diminishing the dough strength. Salinity stress at post anthesis period can shorten the duration of storage proteins accumulation and in turn modify the rate of accumulation of gliadins and glutenins. Likewise, Blumental et al. (1994) observed that heat stress during grain filling caused the increase of gliadin to glutenin ratio because gliadin synthesis continued during heat stress while there was a greatly decreased synthesis of glutenin protein. The studied genotypes varied significantly for the gliadin/glutenin ratio under non-stressed and salt stressed environments. Saint Pierre et al. (2008) found increase in flour protein due to water stress, and in turn more rapidly increase of the percentage of gliadins than glutenins. Khatkar et al. (1995) observed a strong inverse relationship between the gliadin/glutenin ratio and the elasticity of glutens, suggesting that variation in the relative poroportions of gliadin and glutenin may have significant effects on gluten rheology. Additionally, they reported that the elasticity of glutens was more sensitive to changes in the gliadin/glutenin ratio, again emphasising the importance of glutenin subfraction for the rheological properties of a gluten. No significant difference was observed between triticale lines and wheat cultivars for the means of gliadin/glutenin ratio under both environmental conditions (Table 3).

SDS sedimentation volume

Results of the combined ANOVA showed a significant effect of environment, genotype and G × E interaction on the sodium dodecyl sulphate (SDS) sedimentation volume (Table 1). Another study found a highy significant G × E interaction for this trait (Mariani et al., 1995). Although, this interaction has been shown as being more important in determining protein content and endproduct texture, it is less important for measurements associated with gluten strength, such as SDS sedimentation volume (Ames et al., 1999). Under non-stressed environment, means of SDS sedimentation volume ranged from 8.85 ml for F_8 line number 4 to 17.98 ml for 'Kavir' wheat cultivar. 'Roshan' wheat cultivar (14.13 ml) and F_8 line number 5 (6.35 ml) exhibited the highest and the lowest SDS sedimentation volume under salt-stressed experiment, respectively (Table 3). Salinity caused a decrease in SDS sedimentation volume of both triticale and wheat genotypes (Table 3). It is interresting to note that the diminishing effect of salinity on the volume of SDS-sedimentation was associated with a reduction in glutenin

Table 1. Result of combined analysis of variance of the tested traits of triticale and wheat genotypes grown under salinity and normal field conditions.

Source of variation	df	Mean Square										
		Gluten content	TSP	Gliadin	Glutenin	Gliadin/ Glutenin	SDS-sed volume	Protein content	Protein yield	Carbohydrate content	Ash content	Test weight
Environment(E)	1	21.65**	0.07**	0.068**	0.0001	1.29**	71.38**	116.52**	2171176**	551**	0.26**	162457**
Replication(E)	4	0.06	0.0003	0.0001	0.0002	0.006	0.35	0.21	4296	0.42	0.064**	499*
Genotype (G)	19	38.65**	0.016**	0.011**	0.0045**	0.40**	25.35**	6.32**	52714**	3.49**	0.040**	6561**
G×E	19	0.59**	0.0006**	0.00025	0.0003	0.018	1.79**	0.88*	144214*	2.15**	0.022*	1002**
Residual	76	0.25	0.0003	0.00023	0.0002	0.020	0.47	0.44	7915	0.59	0.010	143
CV%		7.26	3.05	4.76	6.47	9.91	7.12	5.00	12.57	1.04	6.11	1.75

TSP: total soluble protein

* and ** significant at P<0.05 and P<0.01, respectively

Table 2. Means of gluten content, TSP (total soluble content), gliadin and glutenin of triticale and wheat genotypes grown under salinity stress and normal field conditions.

Traits	Gluten content (%)		TSP		Gliadin		Glutenin	
Genotype	Non stress	Stress	Non stress	Stress	Non stress	Stress	Non stress	Stress
F_8 lines								
1	3.67k	4.80g	0.520e-i	0.553hi	0.297def	0.333f-i	0.223ef	0.220ef
2	5.59g	6.55de	0.603b	0.657b	0.383a	0.433a	0.220ef	0.223def
3	7.47cd	7.75bc	0.517f-i	0.533ijk	0.283efg	0.307j-m	0.233c-f	0.227def
4	4.65hij	5.21g	0.527d-h	0.534hij	0.340b	0.370bcd	0.187hi	0.173h
5	4.75hij	6.59de	0.553cd	0.590d-g	0.333b	0.363cde	0.220ef	0.227def
6	7.62c	7.89b	0.563c	0.610cd	0.300cde	0.350def	0.263ab	0.260ab
7	7.18cde	7.64bc	0.497ij	0.563gh	0.277e-h	0.333f-i	0.220ef	0.230def
8	4.43ijk	5.20g	0.470jk	0.510k	0.253hi	0.293lm	0.217fg	0.217ef
9	6.78de	7.48bc	0.540c-g	0.570e-h	0.290efg	0.337fgh	0.250abc	0.233cde
DH lines								
1	5.00ghi	6.92cde	0.41l	0.48l	0.243i	0.297klm	0.167i	0.183gh
2	5.72fg	6.14ef	0.513hij	0.563gh	0.320bcd	0.383bc	0.193h	0.180h
3	5.07ghi	5.39fg	0.500hi	0.48l	0.273fgh	0.310i-m	0.227def	0.170h
4	3.96jk	5.53fg	0.443k	0.527ijk	0.247i	0.320g-k	0.197gh	0.207fg
5	7.46cd	7.34bcd	0.517f-i	0.553hi	0.267ghi	0.313h-l	0.250abc	0.240a-e
6	5.28gh	6.94cde	0.533d-g	0.567fgh	0.287efg	0.330f-j	0.247bcd	0.237b-e
7	7.25cde	7.35bcd	0.467k	0.517jk	0.247i	0.287m	0.220ef	0.230def
8	6.45ef	7.31bcd	0.647a	0.700a	0.393a	0.453a	0.253abc	0.247a-d
9	5.30gh	7.18bcd	0.543c-f	0.593def	0.273fgh	0.330f-j	0.270a	0.263a
Roshan	13.87a	14.44a	0.547c-d	0.597de	0.293ef	0.340efg	0.253abc	0.257abc
Kavir	12.80b	13.65a	0.563c	0.630bc	0.323bc	0.390b	0.240cde	0.240a-e
LSD	0.83	0.84	0.028	0.027	0.024	0.026	0.023	0.026

Means within each column with different letters differ significantly at LSD $_{0.05}$

content of flour. This finding is in agreement with that of Francois et al. (1986) who observed dimishing baking quality due to salinity stress and is in the contrary to that of Katerji et al. (2005) who observed a positive effect of salinity stress on SDS sedimentation volume. The discrimination power between genotypes and traits due to salinity stress was improved in the present study due to a higher salinity of irrigation water. Similar contradicroty observations were reported in wheat grown under drought stress conditions. Gooding et al. (2003) reported that restricting moisture before the end of grain filling significantly reduced SDS-sedimentation volume, while Rharrabti et al. (2003) observed that SDS sedimentation volume exhibited good values under rainfed conditions. The reported differences in response of SDS-sedimentation volume trait to salinity and drought probably vary due to different genotypes used, different environmens, and/or the extent of the stresses applied. Triticale lines and wheat cultivars differed significantly for SDS sedimentation volume with the latter being superior under both environmental conditions (Table 3). A positive correlation coefficient was observed between SDS sedimentation volume and gluten content under both environmental conditions of salt-stressed (r =0.85**) and non-stressed experiments (r =0.90**).

Protein content and yield

Results of the combined ANOVA showed significant influence of environment (saline and normal), genotype and their interaction on protein content and protein yield (Table 1). Protein content of genotypes ranged from 10.15% (DH line number 4) to 15.22% (DH line number 3) under non-stressed and 12.65% (DH line number 9) to 15.93% ('Kavir' wheat cultivar) under salt stressed conditions (Table 4). Fernandez-Figares et al. (2000), reported crude protein of triticale values from 8.51% to 17.21%. There was significant difference between means of triticale lines and wheat cultivars for protein content with wheat cultivars being significantly superior (Table 3). Darvey et al. (2000) similarly observed a higher protein content of triticale than wheat. Protein content of cereal is known to be influenced by genotype and environmental conditions. Salinity significantly influenced protein content and caused an increase in protein content (Table 1 and 3). This result was consistent with that of Francois et al. (1986) in durum wheat. Conditions that promote leaf senescence during grain filling tend to increase protein deposition over starch accumulation in the grain, because the production and translocation of carbohydrates to the grain is more sensitive to adverse growing conditions than protein production (Rao et al., 1993; Fernandez-Figares et al., 2000). The rate and duration of both starch and protein deposition in the cereal grain are independent events, controlled and influenced by different factors (Jenner et al., 1991). If the duration of grain filling period is shortened, starch deposition appears to be more sensitive than protein deposition (Bhullar and Jenner, 1985). Therefore, the increase in grain protein percentage obtained in our study, due to salinity in the environment, may be attributed to reduced starch accumulation. Moreover, favorable environmental conditions delay senescence and support nitrogen soil absorption and translocation of its compounds from the leaves, thus producing higher grain yield with a lower protein content than in the salinity environment. In both experiments, grain protein content was negatively correlated with grain yield (r = -0.72**); this is well known relationship in cereals. Fernandez-Figares et al. (2000) found a strong and significant negative relationship between that rates of carbohydrate and protein accumulation in the control plants, indicating the existence of a competition in the transport of proteins and sugars to the grain of triticale under Mediterranean conditions. Indeed, such competition in causing negative relationship between grain yield and grain-protein content is well-documented in triticale (Garcia del Moral et al., 1995) as well as barley and wheat (Jenner et al., 1991). The photosynthetic rate of leaves can show an acute feedback response to internal changes in the demand for assimilates. In this way, conditions that promote high rates of carbohydrate accumulation in the grain tend to delay leaf senescence and the onset of RuBisCo hydrolysis, thus limiting the N available to be remoblised to the grain (Fernandez-Figares et al., 2000). Due to the fact that after salinity treatment the enzyme RuBisCo was rapidly degraded, thus favoring higher N redistribution to the growing grains. A positive correlation was observed between grain yield and protein yield under non-stressed (r =0.87**) and salt-stressed conditions (r =0.94**). Hence, protein yield per hectar was dependent to a greater extent on variation in grain yield than on grain protein content. Grain protein yield decreased when salinity treatment reduced grain yield, even though grain protein percentage increased. There was a positive relationship between protein yield under non-stressed and salt-stressed conditions (Fig. 1). Protein yield ranged from 636.0 kg ha^{-1} for 'Roshan' wheat cultivar to 1024.1 kg ha^{-1} for DH line number 2 under non-stressed experiment and from 405.2 kg ha^{-1} for DH line number 3 to 736.0 kg ha^{-1} for DH line number 2 under salt stressed experiment (Table 3). Under both environmental conditions protein yield means of triticale lines and wheat cultivars differ significantly with triticale lines being significantly superior (Table 3). Millers and bakers are primarily concerned with the functional quality of flour, while wheat and triticale grain yield as the major farmer's targets is inversely related to flour-milling targets.

Carbohydrate content

Salinity significantly influenced carbohydrate content (Table 1) and caused a decrease in the value of this trait (Table 4). The production and translocation of carbohydrate to the grain is more sensitive to adverse growing conditions than protein production (Rao et al., 1993; Fernandez-Figares et al., 2000). Genotypes varied significantly for carbohydrate content under both environmental conditions (Table 4). 'Roshan' wheat cultivar (78.63%) and DH line number 3 (74.43%) exhibited the highest and least carbohydrate content under non-stressed experiment, respectively. Under salt stressed environment, carbohydrate content ranged from 70.33% for DH line number 3 to 73.03% for 'Roshan' wheat cultivar (Table 4). Although no significant difference observed between means of triticale lines and wheat cultivars under salt stress conditions for carbohydrate content, wheat cultivars were significantly superior under non-stress conditions for this trait (Table 4).

Ash content

Results of the combined ANOVA showed that the effects of environment, genotype and G × E interaction on ash content were significant (Table 1). Experimental results have already confirmed a significant role of G × E interactions in determining ash content (Fares et al., 1995). Ash content of almost all of genotypes decreased due to salinity stress (Table 4). Consequently, favourable growing conditions result in higher ash content in whole grain due to increased uptake of

Table 3. Means of the ratio of gliadin to glutenin, SDS-sed volume, protein content and protein yield of triticale and wheat genotypes grown under salinity stress and normal field conditions.

Traits	Gliadin/Glutenin		SDS-sed volume (ml)		Protein content (%)		Protein yield (kg ha^{-1})	
Genotype	Non stress	Stress	Non stress	Stress	Non stress	Stress	Non stress	Stress
F_8 lines								
1	1.33e-h	1.52d-g	9.50cd	6.62fg	10.50k	13.25hij	994.3abc	679.3abc
2	1.75ab	1.95ab	9.20cd	8.80bcd	11.57g-j	13.70g-j	928.8a-f	602.0b-e
3	1.22g-j	1.37e-h	9.73cd	8.57b-e	13.60bc	15.40abc	775.5f-i	514.9d-h
4	1.84a	2.15a	8.85d	8.10de	12.07e-i	13.78f-i	980.6a-d	601.2b-e
5	1.52cde	1.61c-f	9.88cd	6.35g	11.98e-i	14.83a-f	844.5c-g	458.9fgh
6	1.14g-j	1.35gh	9.27cd	8.18de	13.00c-f	14.47c-g	638.3i	575.5b-f
7	1.26f-i	1.45d-h	9.80cd	8.87bcd	12.85c-f	13.80f-i	815.8e-h	604.8b-e
8	1.16g-j	1.35fgh	9.22cd	8.13de	11.92f-i	14.20d-h	868.1a-g	501.4d-h
9	1.16g-j	1.47d-h	10.10c	9.27bc	11.00ijk	13.80f-i	848.3b-g	701.6ab
DH lines								
1	1.46c-f	1.62cde	10.35c	7.58ef	11.32hij	14.00e-h	850.5b-g	607.0b-e
2	1.66abc	2.13a	10.17c	9.08bcd	12.57c-g	15.70ab	1024.1a	736.0a
3	1.21g-j	1.83bc	10.00cd	8.87bcd	15.22a	15.30a-d	811.8e-h	405.2h
4	1.26f-i	1.55d-g	10.13c	6.90fg	10.15k	12.73ij	716.8ghi	610.6a-e
5	1.07ij	1.31gh	9.32cd	8.33cde	13.40bcd	15.10a-e	812.1e-h	533.9d-g
6	1.17g-j	1.39e-h	9.85cd	8.85bcd	12.40d-h	13.95fgh	962.7a-e	581.3b-f
7	1.12hij	1.25h	10.00cd	9.55b	11.95e-i	14.70b-g	847.6b-g	559.8c-f
8	1.56bcd	1.84bc	9.90cd	9.03bcd	12.60c-g	13.80f-i	1011.9ab	671.9abc
9	1.01j	1.26h	9.25cd	8.25cde	11.00ijk	12.65j	824.0d-g	625.8a-d
Roshan	1.16g-j	1.33gh	15.77b	14.13a	13.03cde	14.63b-g	636.0i	412.6gh
Kavir	1.35d-g	1.62cd	17.98a	13.95a	14.20ab	15.93a	657.8hi	485.4e-h
LSD	0.21	0.26	1.21	1.06	1.10	1.10	164.8	126.9

Means within each column with different letters differ significantly at LSD $_{0.05}$.

minerals from the soil (Troccoli et al., 2000). This result is consistent with that of Katerji et al. (2005) who reported a positive effect of salinity on grain quality of tolerant durum wheat by a decrease of the ash content and with that of Francois et al. (1986) who observed a reduction in ash content of semi-dwarf bread and durum wheat deu to soil salinity. This result clearly indicates the disturbing effects of salinity on the uptake, translocation and accumulation processes of mineral elements in the plants. Ash content ranged from 1.53% ('Kavir' wheat cultivar) to 1.97% (DH line number 2) and from 1.33% (DH line number 4) to 1.73% (DH line number 3) under non-stressed and salt stressed environments, respectively (Table 4). Means of ash content of triticale lines and wheat cultivars did not differ significantly under salt-stressed experiment. Under normal conditions, there was a slight difference in ash content of triticale lines and wheat cultivars with triticale being superior (Table 4). Similar observation was also made earlier by Darvey et al. (2000).

Test weight

Results of the combined ANOVA showed the significant effects of environment, genotype and G × E interaction on test weight (Table 1). Salt stress caused a decrease in test weight of the genotypes. Low test weight can occure as a result of various environmental factors such as salinity which can cause shriveling of grain. Test weight ranged from 673 kg m^{-3} (DH line number 3) to 788 kg m^{-3} ('Kavir' wheat cultivar) and from 583 kg m^{-3} (DH line number 1) to 719 kg m^{-3} ('Kavir wheat cultivar) under non-stressed and salt stressed environments, respectively (Table 4). There was significant difference between means of triticale lines and wheat cultivars for test weight with wheat being significantly (P < 0.01) superior under both conditions (Table 4). DH triticale line number 6 had high test weight under both conditions (Table 4). There was no significant correlation between test weight and 1000-grain weight under both conditions. Also, other researcher failed to find any correlation between test weight and 1000-grain weight (Troccoli and Di Fonzo, 1999).

Materials and methods

Plant materials and growth conditions

Field experiments were carried out using 9 DH lines and 9 corresponding F_8 lines of hexaploid triticale (AABBRR) derived from PolonyQ/TW179 cross and two local bread wheat cultivars ('Roshan' and 'Kavir') during the 2008-2009 growing season. 'Roshan' as a drought tolerant and 'Kavir' as a salt tolerant cultivars (Daei et al., 2009) were included as control. Plant materials were grown in two separate experiments under salt stressed and non-stressed conditions at the research farm of Isfahan University of Technology located at Lavark, Iran (40 km south west of Isfahan, 32˚32´N, 51˚23´ E, 1630 m asl). The soil at this site is silty clay loam, typic Haplargids of the arid tropic with pH=7.3-7.8, EC=1-1.2 dS m^{-1} and contained 1.3% of organic matter. Mean annual precipitations and mean annual temperature were 140 mm and 15°C, respectively. Each experiment was conducted using a randomized complete block design with three replications. Each plot consisted of four 4m long rows spaced 25cm apart. At the salt stressed and non-stressed experiments, irrigated water with an EC of 1 dS m^{-1} was used until mid-jointing stage (43 growth stage of Zadoks scale), and afterward salt-stressed experiment was irrigated using saline water by disolving salt in water (1% NaCl). The electrical conductivity (EC) of the irrigation water was nearly 16 dS m^{-1}. EC and chemical properties at 30 cm depth of soil of both saline and non-saline experiments were determined as shown in Table 5.

Table 4. Means of carbohydrate content, ash content, and test weight of triticale and wheat genotypes grown under salinity stress and normal field conditions.

Traits	Carbohydrate content(%)		Ash content (%)		Test weight (kg m^{-3})	
Genotype	Non stress	Stress	Non stress	Stress	Non stress	Stress
F_8 lines						
1	76.53cde	71.67a-f	1.60ef	1.50cd	759b	674de
2	75.20gh	72.67ab	1.57ef	1.63abc	720de	617gh
3	75.00gh	72.03a-e	1.57ef	1.60abc	684hij	648f
4	75.80d-g	72.87ab	1.70cde	1.70ab	750b	696bc
5	76.83bcd	70.37f	1.80bc	1.63abc	693ghi	607hi
6	74.83gh	71.53b-f	1.60ef	1.60abc	729cd	645f
7	75.30gh	70.37f	1.80bc	1.60abc	684hij	653ef
8	75.50e-h	71.93a-e	1.80bc	1.60abc	681ij	643f
9	76.47c-f	71.47b-f	1.67c-f	1.70ab	681ij	589ij
DH lines						
1	76.57cde	72.49abc	1.67c-f	1.60abc	712def	583j
2	75.40fgh	71.00def	1.97a	1.57abc	721de	612h
3	74.43h	70.33f	1.90ab	1.73a	673j	597hij
4	77.00bc	71.17c-f	1.63def	1.33d	748b	654ef
5	75.00gh	70.80ef	1.77bcd	1.70ab	726d	656ef
6	75.23gh	72.33a-d	1.63def	1.63abc	745bc	705ab
7	75.40fgh	71.70a-f	1.70cde	1.63abc	700fgh	635fg
8	75.17gh	72.33a-d	1.77bcd	1.70ab	757b	678cd
9	77.20bc	71.80a-e	1.70cde	1.53bc	708efg	649f
Roshan	78.63a	73.03a	1.70cde	1.63abc	752b	680cd
Kavir	77.70ab	71.60b-f	1.53f	1.57abc	788a	719a
LSD	1.08	1.43	0.16	0.174	17.83	21.58

Means within each column with different letters differ significantly at $LSD_{0.05}$.

Table 5. Electrical conductivity (EC) and soluble ions of the saturated-soil extract in the depth of 30 cm in non-saline and saline fields.

Block (replication)	EC (dS/m)		pH		$Mg^{2+} + Ca^{2+}$(meq L^{-1})		Na^{+}(meq L^{-1})	
	Non-saline	Saline	Non-saline	Saline stress	Non-saline	Saline	Non-saline	Saline
1	1.6	6.1	7.8	7.5	7	24	9	49
2	1.8	5.8	7.9	7.6	7.5	22	10.5	42
3	1.8	5.8	7.9	7.6	7.5	22	10.5	42

Grain quality traits

Dry gluten content (%), gliadin, glutenin, gliadin/glutenin ratio, SDS sedimentation test, grain protein conten (%), protein yield, grain carbohydrate content (%), grain ash content (%),and test weight were evaluatd. Wet and dry gluten contents were determined by AACC Approved Method 38-12 (AACC, 2000). Flour gliadin, glutenin and total soluble protein (TSP) were determined according to Suchy et al. (2007). Eight mg of flour was weighed and poured into 3-ml microcentrifuge test tube and 1.44 ml of 50% (v/v) propan-1-01 at 25°C was added. Each individual sample was vortexed and centrifuged for 30 min at 1000 RPM. After 30 min extraction, the test tubes were vortexed again and centrifuged at 13500 g for 2 min. Ultimately, the absorbance of the supernatant was determined at 280 nm using 50% (v/v) propan-1-01 solution as a blank. This fraction, called 50PS, contains most of the monomeric protein (mostly gliadin) and small amount of glutenin. The TSP was determined exactly as the measuring of gliadin but using a different solvent system of 50% (v/v) propan-1-01 and 0.2% (w/v) DDT and the extraction temperature of 55°C. The spectrophotometer was blanked with 50% (v/v) propan-1-01 and 0.2 (w/v) DDT solution. This fraction as TSP contains 90 to 95 of all protein present in the flour. The amount of glutenin in the flour (50PI) was calculated at the difference between the amount of TSP and amount of gliadin-rich protein (50 PS). TSP, gliadin and glutenin contents were expressed by mean of 4 samples from each plot. SDS-sedimentation volume was determined by the method of Preston et al. (1982). SDS-sedimentation volume was expressed using means of 4 samples from each plot. Grain protein content (%), carbohydrate content (%) and ash content were determined using near-infrared reflectance spectroscopy (NIR) (model 8200, Perten Instruments AB, Sweden).

Statistical analysis

Separate analysis of variance (ANOVA) and combined ANOVA were carried out using data from both salinity stress and normal conditions. Analyses of variances were carried out using PROC GLM of SAS (SAS Institute, 1999). Contrast of triticale lines versus two wheat cultivars and F_8 triticale lines versus DH triticale lines were conducted using orthogonal (independent) comparisons. Mean comparisons were conducted using Fisher's least significant differences (LSDs). Linear regression and correlation analyses were conducted to determine phenotypic relationship between the traits at two different field experimental conditions.

Conclusions

Protein quality and quatity are important in determining dough properties and bread making quality. Salinity causes an increase in protein quantity and a decrease in the protein quality in wheat and triticale. Salinity stress at post-anthesis period can shorten the duration of storage proteins accumulation and, in turn, modify the rate of accumulation of gliadins and glutenins. Moreover, the disruption effects of salinity on the uptake, translocation and accumulation processes of mineral elements in the plants were emphasized. Despite the crucial importance of salinity of soil and water resources in many parts of Iran as a serious threat, the extent of this problem in the farmlands is expanding. In order to overcome the above stated problems in the country and any other countries with similar situation**,** the future basis for targeted breeding strategies for the development of new crop cultivars with enhanced salinity tolerance possessing high yield and quality is emphasized.

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