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Effects of Nacl on Above and Below Growth of Triticale Lines (X. Triticosecal Wittmack) and Barley Cultivar at Two Phynological Stages under Controlled Conditions

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□ ABSTRACT □

The lack of information about the effects of salinity on growth and productivity of triticale prompted us to study the salt tolerance level of 39 triticale lines and barley cultivar subjected to four levels of NaCl: control, 100, 150, 200 mM/L at stem elongation and maturity stages. This study was carried out in greenhouse at ICARDA during 2007, using Randomized Complete design with a factorial arrangement of treatments. Results revealed that the measured characters were affected by NaCl, with an interaction between treatments and lines. The influence of NaCl was observed at the levels 150 and 200 Mm/L more than the 100 Mm/L. Shoot dry weight was affected by salinity more than the root one. NaCl affected the biomass per plant and thousand kernels weight more than plant height, peduncle and spike length. At the two harvesting dates the lines: (14, 32, 13, 30, 34, 16, 10, 26, 19, and 22) characterized by the lowest reduction percentages in almost of measured traits.

Key words: Salinity, NaCl, Triticale (x. Triticosecale Wittmack), Barley.

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تأثير ملح كلور الصوديوم في نمو المجموع الجذري والخضري لسلالات من التريتيكالي (*x. Triticosecale* Wittmack) وصنف شعير في مرحلتين حياتيتين، تحت ظروف متحكم بها.

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□ الملخّص □

إن قلة المعلومات حول تأثير الملوحة في نمو وإنتاجية التريتيكالي عززت أهمية هذا البحث الذي تناول دراسة تحمل 39 سلالة من التريتيكالي وصنف من الشعير لأربعة مستويات من ملح كلور الصوديوم: 0، 100، 150، 200 ميلليمول/ليتر، وذلك خلال مرحلتي تطاول الساق والنضج. أجريت هذه الدراسة في بيت بلاستيكي في المركز الدولي للبحوث الزراعية في المناطق الجافة (إيكاردا) خلال العام 2007، باستخدام تصميم العشوائية الكاملة وفق ترتيب التجارب العاملية للمعاملات المدروسة. أظهرت النتائج أن الصفات المدروسة تأثرت بملح كلور الصوديوم مع وجود فعل متبادل بين المعاملات الملحية والسلالات. لوحظ تأثير الملح في المستويات المرتفعة 150 و200 ميلليمول/ليتر أكثر من المستوى 100 ميلليمول/ليتر. تأثر الوزن الجاف للمجموع الخضري بالملوحة أكثر من الوزن الجاف للجذور. كذلك فإن الكتلة البيولوجية للنبات ووزن الألف حبة قد تأثرتا بشكل أكبر من صفات ارتفاع النبات، وطول حامل السنبلة وطول السنبلة. لوحظ في كل من مرحلتي الدراسة أن السلالات (14، 32، 13، 30، 34، 16، 10، 26، 19، 22) أكثر تحملاً للملوحة مقارنةً بالسلالات الأخرى وصنف الشعير.

الكلمات المفتاحية: ملوحة، ملح كلور الصوديوم، تريتيكالي، شعير.

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Introduction:

Limited potable water availability has resulted in increased use of effluent and other low quality water sources in irrigation (Gill and Rainville, 1994). Although these waters may provide nutrients for plant growth, they often contain significant concentrations of dissolved salts (Harivandi, 1994). Problems associated with saline soils and saline irrigation water may increase in the future as more effluent or poor quality water is applied to turf sites.

Salinity and drought stresses (which often combined with high temperature) are common problems in semi-arid agriculture (Husain et al., 2003), and they are the greatest constraints to cereal grain yield in Mediterranean environments which characterized by hot, dry summers and cool, wet winters (Araus et al., 2003 ; Serrano et al., 1999; Turner and Asseng, 2005). In this climatic conditions, salt may accumulate in the soil because of high evaporative demand and insufficient leaching of ions because of low precipitation (Kerepesi and Galiba, 2000), and this conditions lead to the lake of food and feed production. Therefore, Excessive salinity from soils or irrigation water poses major challenges to crop production around the world (Tanji, 1999; Flowers, 2004).

Soil salinity is responsible for appreciable yield reductions in a range of cultivated crops. Saline soils occupy more than 6% of the world's land area (Szabolcs, 1994; Ghassemi et al., 1995). It is estimated that over800 million hectares of land in the world are affected by both salinity and sodicity (Munns, 2005). In Syria, 45 % of irrigated areas are affected by salinity, these areas are using for crops production (AOAD, 2002). Because of a rapid increase in demand for food production in inevitable due to the world population rising; therefore, there is a need to have salt-tolerant crop genotypes in saline lands for proper cultivation to meet this increasing demand. Achieving this goal may be done using two strategies, (i) reclamation, drainage, and water control can minimize the extent and spread of salinity (Mohanty et al., 1999), but engineering and management costs are high, (ii) breeding of salt-tolerant crops is a promising, energy-efficient approach that may be coordinated with water and land management strategies. Moreover, breeding requires a better understanding of the role of physiological parameters in the salt tolerance of different genotypes so that the traits leading to salt tolerance can be introduced in the new genotypes.

Triticale one of the crops that characterizes by its tolerance to saline soils. Although preliminary studies on the salt tolerance of triticale have been conducted (Francois et al., 1988; Karim et al., 1993), the responses of newly released triticale to salinity are not well known. Francois et al. (1988) found that 7.3 dS m-1 reduced triticale yield by 2.8%. In addition, (Karim et al., 1993) indicated that triticale cultivars gave different responses to varying NaCl (0-200 mM/L).

(Koebner and Martin, 1996) demonstrated that triticale lines which grown under hydroponics system have a high level of salinity tolerance. And there were high difference between cereal crops, where triticale was considered more tolerant than wheat (Tourine et Ammar, 1985).

The results of (Habib et al., 2006) showed the importance of triticale lines which characterized by their superior tolerance to the Drought, Salinity, and double stresses, especially rooting characters (length, weight, volume, and spread through soil categories under drought stress).

Furthermore, the relative importance of the osmotic or toxic effects of NaCl on below growth is not clear in triticale. Therefore, the present study was conducted to determine the effect of various concentrations of NaCl on above and below ground parameters at early and advanced growth stages (stem elongation and maturity) for triticale lines under controlled conditions.

Materials and Methods:

Plant material

Thirty-nine triticale (*x. Triticosecale* Wittmack) lines (TCL1 to TCL39) and one barley cultivar B40 (Arabic aswad) were used in this experiment. Seeds of triticale lines were obtained from CIMMYT, Mexico.

Growth conditions

This experiment was carried out in the greenhouse at Tel Hadya station that belongs to International Center for Agricultural Research in Dry Areas (ICARDA) from the middle of February to the first of June 2007. The air temperature ranged from 20 to 25˚C in the daytime, and from 15 to 18˚C at night. Relative humidity fluctuated between 45 and 85% between day and night. Sandy loam soil was used (3 sand: 1 clay). The soil was dried in the oven, ground, passed through a 5 mm mesh screen, and thoroughly mixed. Five seeds were sown in each pot. One week after sowing, the seedlings were thinned to three per pot. Nitrogen, P and K were applied as 0.05 g NH_4NO_3 per pot, and as 0.05 g KH_2PO_4 per pot. The same amounts were applied three times at 20, 40 and 60 days after sowing. Irrigation was carried out every second day with 150 mL per pot using distill water.

A randomized complete design was used with a factorial arrangement of treatments (cultivars and NaCl concentrations) with three replications for each treatment.

Harvesting dates

Two harvesting dates were performed (stem elongation and maturity) according to Zadoks´s scale (Zadoks´s et al., 1974). Four salt levels [control (T0), 100 (T100), 150 (T150), and 200 (T200) mM/L of NaCl] in the soil were applied after emergence of the 3rd leaf.

Measurements

At stem elongation stage for all genotypes, shoot length and tillers number for each plant were measured, then the pots were cut to obtain roots by washing them with effluent water. After washing roots, each plant was separated into shoot and root. Total shoot fresh weight was recorded. Samples of shoot and root were dried in the oven at 70º C for 48 h to measure dry weight and then to estimate Root/Shoot Ratio (R/A). Height of the main stem to the base of the ear, peduncle length, spike length, biomass per plant, and thousand-kernel weight (TKW) were measured for each plant at maturity stage.

Statistical analysis

Statistical analysis was done by GenStat Version 10; when an *F*-test indicated significant differences between treatments, multiple comparisons were made, with least significant differences (LSD). The mean separation was done using Duncan´s multiple range test. Reduction percentages for both root and shoot dry weight, shoot length, tillers number, biomass per plant, plant height, and TKW for each line were subjected to cluster analysis, for the purpose of grouping the lines into clusters.

Results:

Shoot length and tillers number

Table (1) shows the average of shoot length for all Triticale clusters varied between

(49.1 and 57.2 cm) in (T0), and between (41.3 and 48.4 cm) in the highest NaCl concentration (T200), whereas the means of barley cultivar were (48 and 36.7 cm) for (T0) and level (T200) respectively.

Tillers number for almost of Triticale lines ranged from 3 to 4 tillers in (T0), and from 1.7 to 2.3 tillers at the level (T200). However, the means of this trait in barley cultivar were 9 tillers at (T0), and 3.3 tillers at (T200). (Appendix 1)

The effect of increasing NaCl levels on shoot length and tillers number was differed relative to lines and NaCl concentration (Table1). Increasing NaCl level reduced tillers number rather than affecting the shoot length in all triticale lines and barley cultivar. It was observed that the shoot length at salinity level (T100) did not differ significantly in comparison to control in most of triticale lines, whereas tillers number were more affected .

Lines x NaCl interaction were not significant for shoot length, and tillers per plant (table1). Means shoot length varied between 44.3 and 67.3 cm in(T0), whereas ranged between 36.7 and 54.3 cm in the highest NaCl concentration (T200). (Appendix 1).

In general, some of studied triticale lines characterized by their superiority upon barley cultivar; this superiority was explained by low reduction percentages between (T0) and the highest level of NaCl (T200) for those lines which ranged from (15%) to (18%) for shoot length, and from (40%) to (45%) for tillers number, whereas these values were (24 and 63%) for shoot length and tillers number respectively in barley cultivar.

Table1. Mean value for shoot length and tillers per plant in 39 triticale lines and one cultivar of barley, at the beginning of stem elongation.

	Shoot length					Tillers per plant				
	T0	T100	T150	T200	Mean	T0	T100	T150	T200	Mean
Triticale										
Cluster1	49.1	47.4	42.5	41.3	45.0	3.5	2.7	2.1	2.0	2.6
Cluster2	57.2	55.5	51.8	48.4	53.2	3.0	2.7	2.2	1.8	2.4
Cluster3	53.7	52.2	47.4	44.0	49.3	3.4	2.8	2.3	1.9	1.9
Barley	48.0	44.7	40.3	36.7	42.4	9.0	7.7	6.0	3.3	6.5
Mean	52.0	49.9	45.5	42.6		4.7	4.0	3.4	2.3	
LSDs	C= 2.4***; T= 2.4***; CxT= 4.9 ns					C= 1.2***; T= 1.2**; CxT= 2.5 ns				

C: Cluster; T: NaCl treatment; CxT: Cluster x Treatment;
* significant <0.05; **significant<0.01; ***significant<0.001; ns: non-significant.

Dry weight of shoot and root

Dry weight of shoot and root varied among introduced lines within levels of NaCl (Table 2). Eight lines produced dry weight of shoot equal or greater than (1 g) per plant through the four salinity levels, whereas the other lines and barley cultivar recorded dry shoot weight greater than (1 g) at (T0) and (T100) treatments, and less than (1 g) at levels (T150 and T200). Furthermore, the lines that showed dry shoot weight greater than (1 g) within all salinity levels, had the lowest reduction percentages for both shoot and root dry weight, and less than that for other lines and barley cultivar. (Appendix 2)

In general, dry shoot weight among clusters ranged from 1.14 to 1.48 g per plant at (T0), and from 0.6 to 0.94 g per plant at the highest NaCl concentration (T200). Increasing of NaCl concentration adversely affected shoot dry weight (Table 2).Considering each line, shoot dry weight fluctuated with varying NaCl concentrations. The lowest values were observed at the highest level of NaCl (T200). Moreover, the interaction between lines and NaCl concentration was not significant. Although this interaction, some triticale lines showed a little affecting in comparison with barley cultivar and the rest of triticale lines.

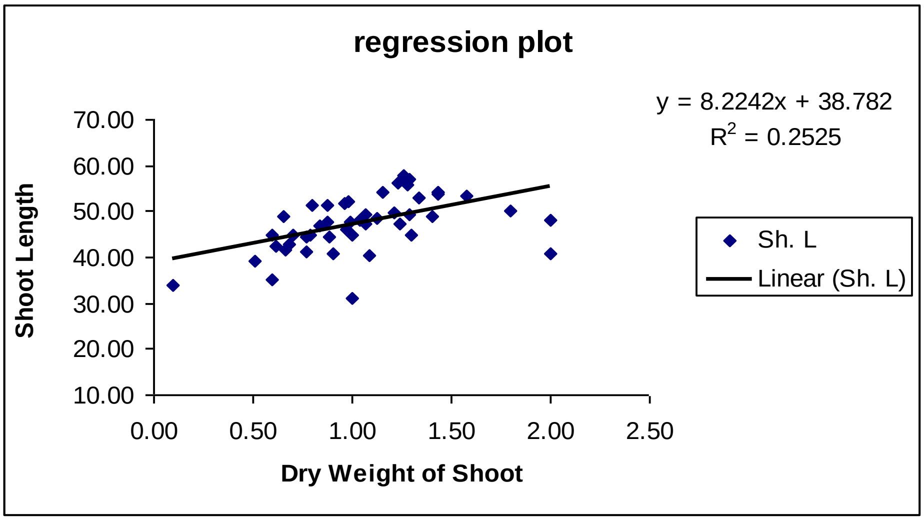
In terms of root dry weight, differences among the lines and between treatments were significant, whereas there is not interaction between lines and NaCl concentration. No significant change in the root dry weight was observed at the lowest NaCl concentration (T100); however, higher NaCl concentrations resulted in a significant reduction in this parameter (table 2).

Table2. Mean value for shoot and root dry weight in 39 triticale lines and one cultivar of barley, at the beginning of stem elongation.

	Dry weight of shoot per plant					Dry weight of root per plant				
	T0	T100	T150	T200	Mean	T0	T100	T150	T200	Mean
Triticale										
Cluster1	1.14	0.96	0.73	0.60	0.86	0.48	0.38	0.25	0.21	0.33
Cluster2	1.28	1.22	0.94	0.75	1.05	0.61	0.47	0.37	0.29	0.44
Cluster3	1.48	1.35	1.10	0.94	1.22	0.62	0.50	0.34	0.28	0.43
Barley	1.67	1.50	0.80	0.73	1.18	0.37	0.33	0.17	0.10	0.24
Mean	1.39	1.26	0.89	0.76		0.52	0.42	0.28	0.22	
LSDs	C= 0.15 ***; T= 0.15***; CxT= 0.31 ns					C= 0.06***; T= 0.06***; CxT= 0.11 ns				

C: Cluster; T: NaCl treatment; CxT: Cluster x Treatment;
* significant <0.05; **significant<0.01; ***significant<0.001; ns: non-significant.

The relationship between shoot length and both of shoot and root dry weight could be represented by the following figures.



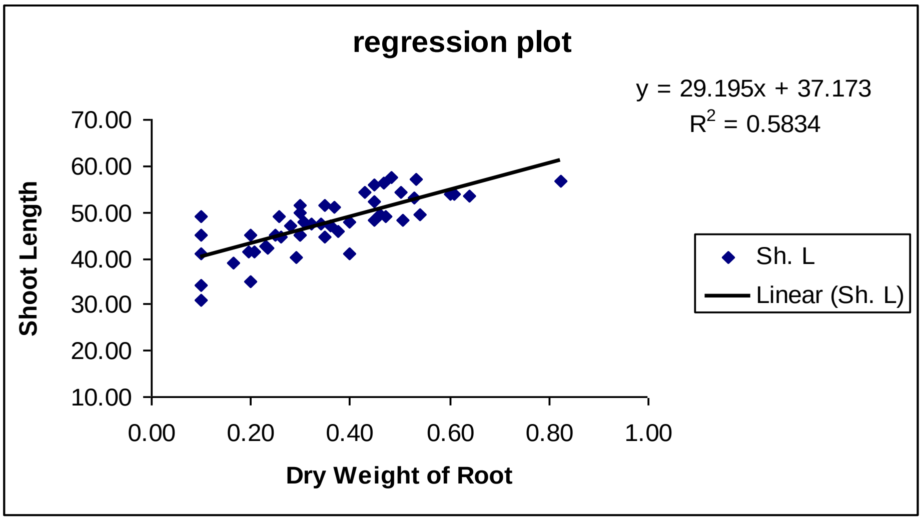


Figure 1. Relationships between shoot length and both of shoot and root dry weight for triticale lines and barley cultivar within the NaCl concentrations.

There were significant differences for the lines and NaCl concentration with respect to the root to shoot dry weight ratio (R/A). Increased NaCl concentration caused a remarkable increase in the R/A in some triticale lines, and the highest ratio (0.63) was observed at the level (T200) of NaCl. (Figure 2).

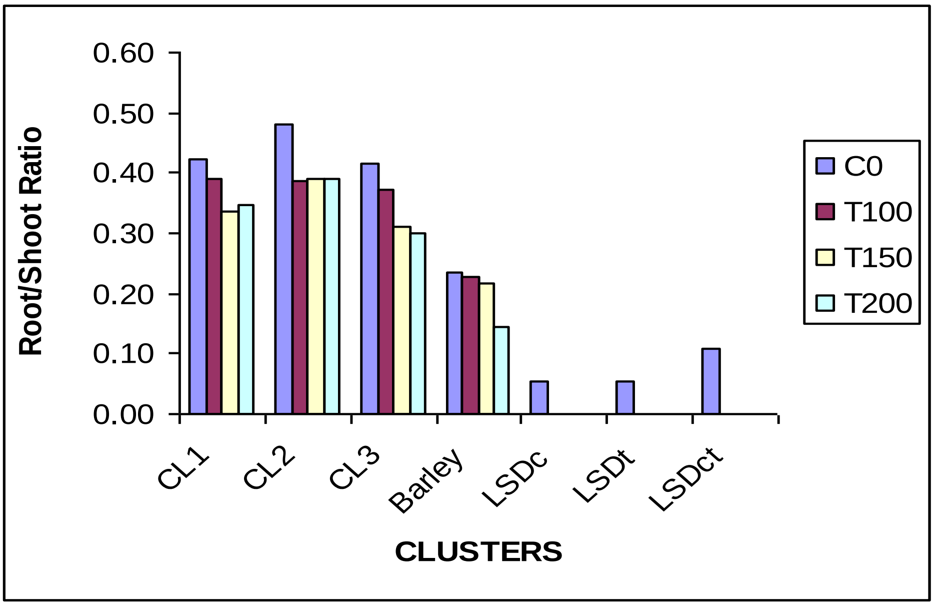


Figure 2. Mean value for R/A in 39 triticale lines and one cultivar of barley at the beginning of stem elongation.

Plant height, peduncle and spike length

Plant height for all lines was affected by increasing NaCl concentration, and it was reduced by (11 to 30%) for triticale lines, and by (20.5%) for barley cultivar at level (T200), whereas the differences between control and levels (T100 and T150) were ranged from little decreasing and little increasing (Appendix 3).

The same trend was observed for spike length which reduced by (3 to 33%) for triticale lines, and by (15%) for barley cultivar at level (T200). Although the length of peduncle at level (T100) was better than control in almost of the lines, the values of this parameter were fluctuated at the highest NaCl concentration (T200) (figure3).

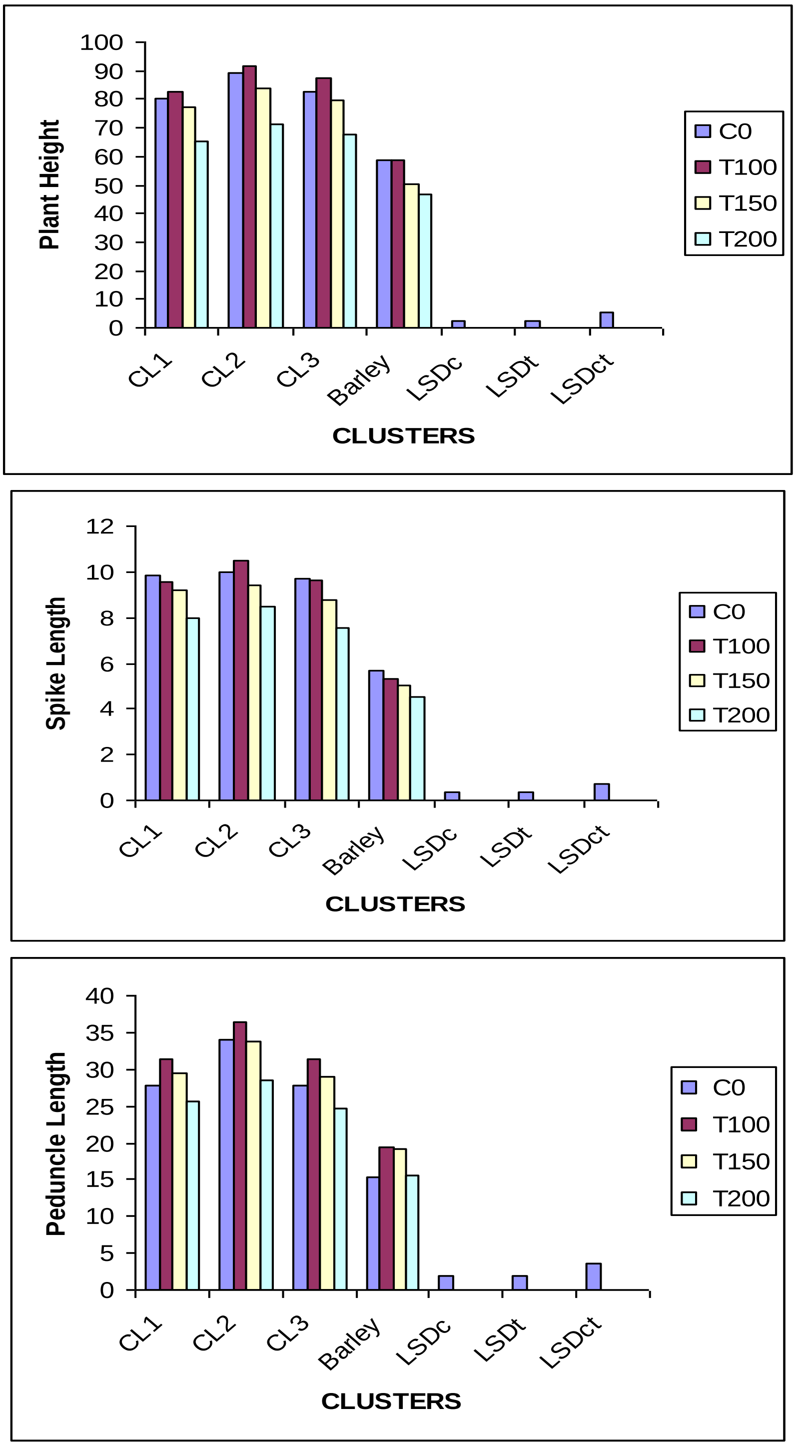


Figure 3: Mean value for Plant height, Peduncle and Spike length at maturity in 39 triticale lines and one cultivar of barley.

Biomass per plant and TKW

Analysis of variance for biomass and TKW revealed that these characters were affected by salinity treatments, and there were interaction between lines and NaCl concentrations just for TKW. In fact, the influence of the NaCl treatments was observed in the high concentrations (T150 and T200) more than the low one (T100), and this influence can be explained by the following reduction percentages (33 and 59%) for biomass per plant at levels (T150 and T200) respectively, and (35 and 47%) for TKW at the same levels that mentioned above.

Appendix 4 shows that the average of biomass per plant for all the introduced triticale lines and barley cultivar was greater than 10 g at control treatment (T0). The biomass per plant decreased into 5.27 g at the highest NaCl level (T200).

Figure (3) represented the averaged across lines, the relationships between TKW and both of plant height and biomass per plant within the levels of NaCl.

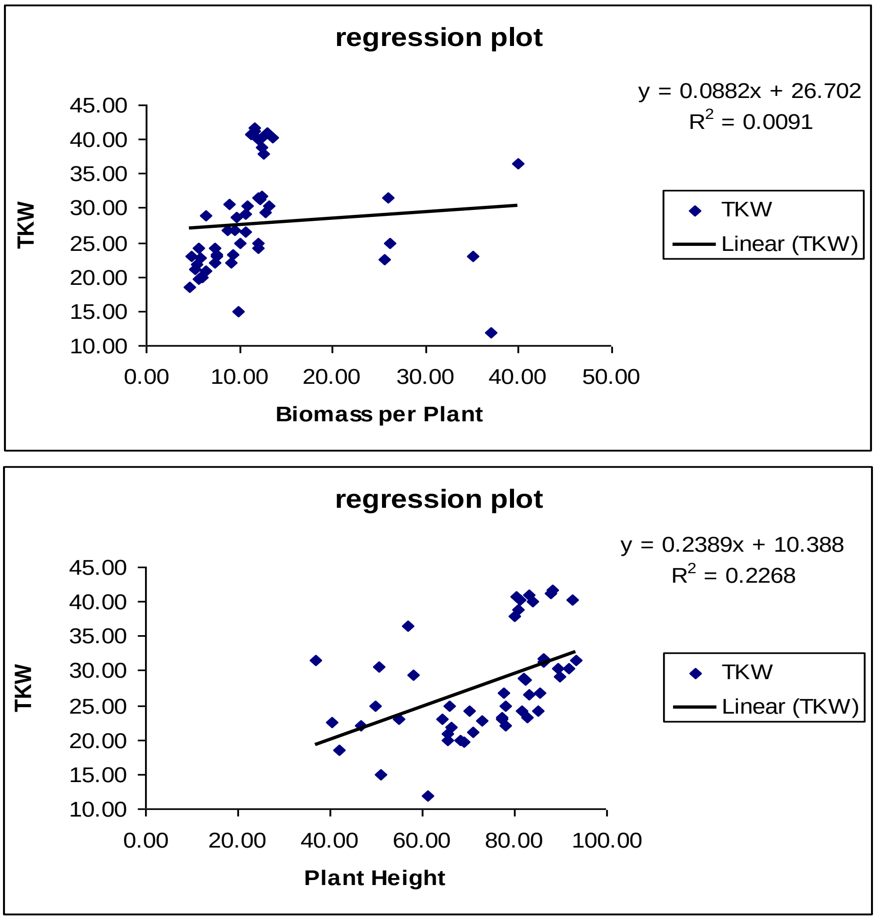


Figure 4. Relationships between TKW and both of plant height and biomass per plant for triticale lines and barley cultivar within the NaCl concentrations.

Table 3 shows that the average of biomass per plant for all the clusters of triticale lines and barley cultivar was greater than 10 g at control treatment (T0). The biomass per plant decreased into 5.5 g at the highest NaCl level (T200).

TKW differed between lines among each NaCl concentration. The average of this character varied between 39.2 and 41.1 g at T0, and ranged from 19.9 to 22.7 g at the level T200 for triticale clusters, while barley cultivar recorded 35.8, and 18.5g at the same levels respectively.

Table 3. Mean value for Biomass/plant at maturity in 39 triticale lines and one cultivar of barley.

	Biomass per plant					TKW				
	T0	T100	T150	T200	Mean	T0	T100	T150	T200	Mean
Triticale										
Cluster1	12.1	10.8	8.5	5.5	9.2	39.2	26.5	23.7	21.9	9.2
Cluster2	11.9	11.2	7.5	5.5	9.0	41.1	30.4	26.6	22.7	9.0
Cluster3	12.9	12.6	9.3	5.8	10.1	40.4	31.1	24.1	19.9	10.1
Barley	10.4	10.1	5.8	5.1	7.9	35.8	30.0	26.2	18.5	20.4
Mean	16.7	15.1	11.0	6.0		39.1	15.1	11.0	6.0	
LSDs	C= 4.46***; T= 4.36***; CxT= 8.72 ns					C= 3.18**; T= 3.18***; CxT= 6.36*				

C: Cluster; T: NaCl treatment; CxT: Cluster x Treatment;
* significant <0.05; **significant<0.01; ***significant<0.001; ns: non-significant.

Classification of introduced lines

Grouping of the introduced lines based on the reduction percentages for root dry weight, shoot dry weight, shoot length, tillers number, biomass per plant, and TKW is presenting in table (4). Lowest reduction percentages for almost parameters characterized cluster1. Cluster2 had lower values of reduction percentages for TKW, biomass per plant, root and shoot dry weight than cluster3, which characterized by lower reduction percentage values for shoot length, tillers number, and plant height. However, for barley cultivar, it belongs to cluster2, which was intermediate between cluster1 and cluster3.

Table 4. Classification of introduced lines based on reduction percentages for root dry weight, shoot dry weight, shoot length, tillers number, biomass per plant, plant height, and TKW.

Reduction percentages %	Cluster		
	1	2	3
Root dry weight	13.1 (44)	26.4 (55.6)	15.3 (56.6)
Shoot dry weight	7.2 (35.1)	24.2 (43.6)	+0.5 (15.1)
Shoot length	1.6 (13.6)	4.2 (18.3)	3.9 (15.1)
Tillers No.	7.9 (32.9)	27.6 (44.6)	14.9 (42.7)
Biomass per plant	3.9 (42.8)	8.1 (54.4)	5.8 (60.6)
Plant height	0.15 (18.6)	+3.7 (18.8)	+6.9 (17.7)
TKW	8.3 (32.9)	14.1 (37.4)	21.5 (46.6)

Numbers out of parentheses are reduction at the lowest NaCl level (T100); numbers in parentheses are reduction at the highest-level (200mM/L). Numbers with (+) means increasing upon control.

Discussion:

Growth and yield were markedly reduced by salinity treatments, but differences between lines appeared especially at the high NaCl levels (150 and T200). Increasing NaCl concentration antagonistically affected shoot and root dry weight Furthermore, the shoots were more sensitive than roots as the NaCl concentration increased. These results are similar to those reported by (Gupta and Srivastava, 1989), who found that the root parts were less affected than the shoot in wheat. (Dudeck et al., 1983) also found that, as the salt concentration increased, root growth of bermudagrass increased to a maximum point and then declined. It was reported that the root growth in triticale was much better than that in rye and wheat in varying (0.75 and 150 mM NaCl) salt treatments (Salim, 1991).

Increased NaCl levels caused a remarkable increase in the root/shoot ratio. This means that triticale shoots were more severely affected by NaCl than the roots, as reported by (Salim, 1991) and (Atak et al., 2006).

The osmotic stress of the NaCl outside the roots reduced the formation of new leaves, by inhibiting development of both leaf and tiller primordial, this results (reducing tillers per plant) is in agreement with (Hausain et al., 2003) who concluded that the Na^+ specific effect affects the function and longevity of mature leaves, with high Na^+ accumulation acceleration leaf senescence. However, if old leaves die faster than new ones are produced, then, the proportion of leaves that are injured starts to increase, and inadequate assimilate supply may limit further growth and a decreasing in shoot dry weight will be observed (Husain et al., 2003).

Among morphological traits, plant height was the most parameter that affected by increasing NaCl concentration, and this in agreement with (Greenway and Munns, 1980) who attribute the salinity inhibition for plant growth to water deficit, ion toxicity, and ion imbalance.

A major effect of the salinity treatments was a reduced in tillers production. (Francois et al., 1994) found that the yield reducing effect of salinity was mainly through the effect on tiller production, when plants experienced salinity during the vegetative stage. A reduction in the number of ear-bearing tillers accounted for most of the yield reduction observed in studies of salt-stressed bread wheat (Maas et al., 1996) and durum wheat (Maas and Grieve, 1990). Although (James et al., 2002) showed that chlorophyll retention is only one indicator of leaf photosynthetic under saline conditions, (Husain et al., 2003) reported that at the high level of salinity, other factors that may have influenced net carbon gain were more important than chlorophyll retention, such as reduction in leaf size, rate of photosynthesis, or tiller number.

Biomass per plant and TKW for almost of browse lines at the lowest NaCl level (100mM/L) were reduced less than the highest one (T200). The mechanism by which salinity affects biomass and TKW can be due to the salt outside the roots, or the salt accumulating in the leavesumber. (Munns, 2002). As (Scardaci et al., 1996) and (Shannon et al., 1998) reported, reduction in seedling growth and loss of stand due to salinity have been implicated as causative factors for yield losses in California rice production

The groupings in table 4 allow us to recognize three groups were clustered according to the reduction percentages in studied parameters. The classification of the introduced triticale lines in the current study should, however, be interpreted with caution because although some of them recorded a low reduction percentages in comparison with barley cultivar, there is no documentation on their potential as forage in marginal lands in Mediterranean region. Secondly, table 4 shows that barley cultivar belongs to cluster 2 which contain lines characterized by intermediate reduction percentages between cluster1 and cluster3.

A better understanding of physiological responses (active accumulation of compatible solutes such as amino acids, polyamines, and carbohydrates) under these conditions may help in programs in which the objective is improve the drought and / or salt tolerance of crop varieties (Kerepesi and Galiba, 2000; Martin et al., 1993; Galiba, 1994; McKersie and Leshem, 1994; Colmer et al., 1995; Rosa-Ibarra and Maiti, 1995).

Appendices:

Appendix 1. Mean value for shoot length and tillers No per plant, in 39 triticale lines and one cultivar of barley at the beginning of stem elongation in.

Entry No.	Shoot length /cm/				Tillers No./plant			
	T0	T100	T150	T200	T0	T100	T150	T200
TCL1	47.3 jn	41.7 ik	40.7 ko	40.0 c	3.7 a	2.3 ac	1.7 b	1.7 bc
TCL2	52.0 dl	40.0 k	39.0mo	37.3 c	4.0 a	3.0 ac	2.0 ab	1.7 bc
TCL3	47.0 jn	52.3 bf	40.3 lo	43.0 ac	3.7 a	3.3 ab	2.7 ab	2.3 ac
TCL4	48.0 jn	40.7 jk	37.7 o	40.3 bc	3.0 a	2.7 ac	2.0 ab	2.3 ac
TCL5	48.7 in	47.3 ek	41.3 jo	38.3 c	3.7 a	3.0 ac	2.0 ab	2.3 ac
TCL6	44.3 n	47.7 ek	45.0 go	41.7 ac	3.0 a	3.0 ac	2.7 ab	2.0 ac
TCL7	54.0 cj	50.3 ch	43.7 ho	40.3 bc	3.3 a	2.7 ac	2.0 ab	2.0 ac
TCL8	51.0 gn	49.3 di	38.7 no	40.0 c	3.7 a	2.3 ac	2.0 ab	1.7 bc
TCL9	53.0 ck	47.3 ek	41.3 jo	42.0 ac	4.0 a	2.0 bc	2.0 ab	2.0 ac
TCL10	47.0 jn	46.3 fk	43.7 ho	43.7 ac	3.3 a	3.0 ac	2.0 ab	2.7 ab
TCL11	45.7 ln	43.0 hk	40.3 lo	41.7 ac	3.3 a	3.0 ac	2.0 ab	2.0 ac
TCL12	47.7 jn	45.7 fk	42.7 io	39.7 c	3.3 a	2.0 bc	2.0 ab	2.0 ac
TCL13	47.7 jn	50.7 ch	46.0 fn	46.0 ac	3.0 a	3.0 ac	2.0 ab	2.3 ac
TCL14	56.0 ch	59.7 ab	56.3 ab	53.3 ab	3.0 a	3.0 ac	2.7 b	2.3 ac
TCL15	46.0 kn	43.7 gk	41.3 jo	40.3 bc	3.3 a	3.3 ab	2.0 ab	2.3 ac
TCL16	57.3 bg	52.3 bf	48.0 dl	47.7 ac	2.7 a	2.3 ac	2.7 ab	2.3 ac
TCL17	53.7 cj	50.0 ch	44.0 ho	45.3 ac	3.7 a	3.0 ac	2.7 ab	2.0 ac
TCL18	54.0 cj	51.3 ch	48.7 cj	54.3 a	3.0 a	2.7 ac	2.3 ab	2.0 ac
TCL19	53.0 ck	50.0 ch	47.7 dl	48.7 ac	2.7 a	2.7 ac	2.7 b	2.0 ac
TCL20	59.7 bc	57.7 ad	51.7 bg	44.7 ac	4.0 a	2.7 ac	1.7 b	1.7 bc
TCL21	49.7 hn	47.3 ek	42.0 jo	43.0 ac	3.3 a	2.7 ac	2.0 ab	2.0 ac
TCL22	53.7 cj	50.7 ch	48.3 dk	47.7 ac	3.0 a	3.0 ac	2.3 ab	2.0 ac
TCL23	51.7 em	50.0 ch	45.7 gn	44.0 ac	3.0 a	2.3 ac	2.7 ab	1.7 bc
TCL24	59.0 bd	59.7 ab	51.7 bg	46.3 ac	3.0 a	2.7 ac	1.7 b	1.0 c
TCL25	58.7 be	61.0 a	56.0 ac	47.7 ac	2.7 a	2.3 ac	2.0 ab	2.0 ac
TCL26	58.3 bf	57.3 ad	54.0 ae	45.3 ac	3.0 a	2.7 ac	2.3 ab	2.0 ac
TCL27	63.7 ab	55.7 ae	54.3 ad	48.3 ac	3.3 a	3.0 ac	2.3 ab	1.0 c
TCL28	67.3 a	60.7 a	52.0 ag	48.7 ac	3.7 a	3.3 ab	2.7 ab	1.0 c
TCL29	50.0 hn	51.0 ch	46.7em	38.7 c	2.7	3.0 ac	1.7 b	1.3 bc
TCL30	49.3 hn	48.3 ej	45.7 gn	43.0 ac	3.3a	3.0 ac	3.0 ab	2.0 ac
TCL31	52.0 dl	51.7 bg	53.3 af	49.0 ac	3.7 a	3.7 a	3.7 a	2.0 ac
TCL32	53.3 cj	57.3 ad	59.0 a	48.7 ac	3.3 a	2.7 ac	2.3 ab	2.3 ac
TCL33	55.3 ci	57.7 ad	50.0 bi	39.3 c	2.7a	2.7 ac	2.7 ab	1.7 bc
TCL34	50.0 hn	50.7 ch	50.7 bh	44.0 ac	3.3 a	3.0 ac	2.7 ab	2.0 ac
TCL35	51.7 em	51.3 ch	43.7 ho	41.7 ac	3.3 a	2.7 ac	1.7 b	1.7 bc
TCL36	52.3 dl	50.7 ch	45.7 gn	40.0 c	3.7 a	2.0 bc	1.7 b	1.7 bc
TCL37	58.7 be	58.0 ac	45.3 gn	47.7 ac	3.7 a	1.7 c	1.7 b	2.0 ac

TCL38	51.3 fn	52.0 bg	48.0 dl	43.3 ac	3.7 a	2.7 ac	2.7 ab	1.7 bc
TCL39	58.0 bg	55.0 ae	47.3 dl	47.7 ac	3.7 a	2.7 ac	2.3 ab	2.0 ac
B40	48.0 jn	44.7 gk	40.3 lo	36.7 c	9.0	7.7	6.0	3.3 a
Mean	52.54	50.77	45.94	44.40	3.425	2.892	2.317	1.950
Prob.	S***; L***; S x L*				S***; L***; S x L ns			

S: NaCl; L: Lines; SxL: NaCl x Lines; * significant <0.05; **significant<0.01; ***significant<0.001; ns: non-significant. Means values followed by the same letter in each column indicate non-significant differences.

Appendix 2. Mean value for shoot and root dry weight in 39 triticale lines and one cultivar of barley at the beginning of stem elongation.

Entry No.	Dry weight of shoot g/plant				Dry weight of root g/plant			
	T0	T100	T150	T200	T0	T100	T150	T200
TCL1	1.00 de	0.57 lm	0.53 hi	0.53 c	0.37 c	0.30 de	0.17 e	0.17 ce
TCL2	1.30 ae	0.90 gm	0.87 di	0.57 c	0.80 ac	0.40 ce	0.30 ce	0.27 ae
TCL3	1.23 ae	1.40 ag	0.83 di	0.53 c	0.43 bc	0.47 be	0.23 de	0.13 de
TCL4	1.30 ae	0.87 hm	0.63 gi	0.70 bc	0.47 bc	0.33 ce	0.27 ce	0.27 ae
TCL5	1.07 ce	0.53 m	0.73 gi	0.47 c	0.43 bc	0.43 be	0.27 ce	0.13 de
TCL6	1.13 ae	1.27 cj	1.13 ae	0.40 c	0.43 bc	0.53 ae	0.23 de	0.17 ce
TCL7	0.97 e	0.87 hm	0.63 gi	0.60 c	0.47 bc	0.47 be	0.27 ce	0.27 ae
TCL8	1.27 ae	0.83 im	0.67 fi	0.57 c	0.67 ac	0.37 ce	0.23 de	0.23 be
TCL9	1.30 ae	0.97 fm	0.80 ei	0.70 bc	0.33 c	0.33 ce	0.30 ce	0.27 ae
TCL10	0.97 e	1.23 cj	0.70 ei	0.70 bc	0.53 bc	0.47 be	0.30 ce	0.30 ae
TCL11	0.97 e	0.93 gm	0.83 ei	0.90 ac	0.47 bc	0.33 ce	0.27 ce	0.27 ae
TCL12	1.10 be	0.93 gm	0.73 ei	0.60 c	0.47 bc	0.33 ce	0.27 ce	0.20 be
TCL13	1.50 ae	1.37 ah	1.13 ae	1.00 ac	0.37 c	0.37 ce	0.27 ce	0.23 be
TCL14	1.27 ae	1.33 bi	0.97 ch	0.90 ac	0.67 ac	0.50 ae	0.40 be	0.40 ad
TCL15	1.13 ae	1.13 dk	0.83 ei	0.50 c	0.47 bc	0.40 ce	0.27 ce	0.13 de
TCL16	1.07 ce	0.97 fm	0.80 ei	0.80 ac	0.47 bc	0.40 ce	0.37 be	0.30 ae
TCL17	1.23 ae	1.13 dk	0.97 ch	0.83 ac	0.53 bc	0.53 ae	0.27 ce	0.27 ae
TCL18	1.33 ae	1.00 em	0.93 ci	0.57 c	0.87 ab	0.47 be	0.40 be	0.13 de
TCL19	1.23 ae	1.13 dk	0.97 ch	0.90 ac	0.50 bc	0.43 be	0.37 be	0.30 ae
TCL20	1.70 ab	1.13 dk	0.87 di	0.67 bc	0.63 ac	0.40 be	0.27 ce	0.17 ce
TCL21	1.00 de	0.80 jm	0.50 i	0.43 c	0.33 c	0.27 e	0.17 e	0.13 de
TCL22	1.13 ae	0.87 hm	0.83 di	0.80 ac	0.47 bc	0.47 be	0.30 ce	0.30 ae
TCL23	1.33 ae	1.13 dk	0.87 di	0.57 c	0.60 bc	0.47 be	0.30 ce	0.27 ae
TCL24	1.40 ae	1.50 ae	1.03 bg	0.87 ac	0.50 bc	0.47 be	0.23 de	0.27 ae
TCL25	1.37 ae	1.67 ac	1.00 bg	0.67 bc	0.50 bc	0.60 ad	0.37 be	0.23 be
TCL26	1.50 ae	1.47 af	1.10 af	1.03 ac	0.70 ac	0.63 ac	0.53 ab	0.53 a
TCL27	1.37 ae	1.07 dl	0.87 di	0.50 c	0.43 bc	0.40 be	0.30 ce	0.23 be
TCL28	1.23 ae	1.37 ah	0.97 ch	0.50 c	1.07 a	0.37 ce	0.37 be	0.17 ce
TCL29	1.20 ae	1.80 ab	0.67 fi	0.60 c	0.60 bc	0.70 ab	0.20 e	0.17 ce
TCL30	1.10 be	0.97 fm	0.70 ei	0.47 c	0.43 bc	0.40 be	0.27 e	0.27 ae
TCL31	1.33 ae	1.47 af	1.30 ac	1.00 ac	0.63 ac	0.60 ad	0.63 a	0.43 ac
TCL32	1.07 ce	1.17 ck	0.93 ci	0.90 ac	0.60 bc	0.50 be	0.47 ad	0.37 ae

TCL33	1.60 ad	1.53 ad	1.27 ad	1.37 ab	0.43 bc	0.33 de	0.33 be	0.17 ce
TCL34	1.60 ad	1.03 dm	1.40 ab	0.87 ac	0.53 bc	0.40 be	0.33 be	0.23 be
TCL35	1.40 ae	1.20 cj	0.77 ei	0.73 bc	0.63 ac	0.30 de	0.27 ce	0.20 be
TCL36	1.23 ae	0.67 km	0.63 gi	0.57 c	0.47 bc	0.30 de	0.20 e	0.20 be
TCL37	1.73 a	1.83 a	1.50 a	1.43 a	0.73 ac	0.53 ae	0.30 ce	0.37 ae
TCL38	1.17 ae	1.17 ck	0.93 ci	0.83 ac	0.73 ac	0.37 ce	0.27 ce	0.23 be
TCL39	1.60 ad	1.33 bi	1.03 bg	1.03 ac	0.90 ab	0.77 a	0.50 ac	0.47 ab
B40	1.67 ac	1.50 ae	0.80 ei	0.73 bc	0.37 c	0.23 e	0.17 e	0.10 e
Mean	1.28	1.51	0.89	0.73	0.55	0.43	0.31	0.25
Prob.	S***; L***; S x L*				S***; L***; S x L ns			

S: NaCl; L: Lines; SxL: NaCl x Lines; * significant <0.05; **significant<0.01; ***significant<0.001; ns: non-significant. Means values followed by the same letter in each column indicate non-significant differences.

Appendix 3. Mean value for Peduncle and Spike length at maturity in 39 triticale lines and one cultivar of barley.

Entry	Peduncle length /cm/				Spike length /cm/			
	T0	T100	T150	T200	T0	T100	T150	T200
TCL1	25.9 km	28.0 hm	27.5 hm	26.1 ae	10.2 af	9.6 cl	9.7 ah	6.4gi
TCL2	18.3 n	24.1 mn	22.3 mn	18.6 ag	10.1 af	9.9 bj	8.8 cl	7.7 bi
TCL3	17. 7 n	26.1 im	27.1 im	18.7 fh	9.8 ag	9.7 ck	9.1 bl	7.5 bi
TCL4	29.0 em	29.6 el	29.1 el	28.2 ae	9.7 bg	9.2 fm	8.7 dl	7.2 ci
TCL5	26.0 km	27.2 lm	25.0 lm	24.0 cg	10.5 ad	11.0 ag	9.3 aj	8.0 ah
TCL6	30.8 dj	35.4 cl	29.5 cl	29.0 ae	12.3 a	11.6 ab	10.4 ae	8.4 ah
TCL7	31.0 dj	31.3 ak	31.8 ak	28.2 ae	11.8 ab	10.9 ag	9.6 ai	8.2 ah
TCL8	25.1 m	30 bl	30.6 bl	27.2 ae	11.3 ac	10.5 ag	10.0 af	9.2 ad
TCL9	33.4 af	38.3 ah	33.4 ah	25.7 ag	8.3 dg	7.7 mn	8.0 fl	7.1 di
TCL10	29.1 em	35.0 ak	32.0 ak	26.6 ae	7.7 eh	7.7 mn	7.8 gl	7.9 bh
TCL11	28.5 gm	31.7 bl	31.0 bl	26.3 ae	7.8 eh	7.7 mn	7.4 jl	7.3 ci
TCL12	31.6 ci	32.1 aj	32.2 aj	26.7 ae	7.3 gh	7.3 n	7.6 il	6.7 ei
TCL13	28.8 fm	33.7 ak	32.0 ak	27.3 ae	7.9 eh	8.5 hn	7.2 kl	6.7ei
TCL14	35.6 ac	38.4 af	34.5 af	28.3 ae	8.3 dg	8.0	8.9 bl	7.3 ci
TCL15	28.2 hm	35.1 dl	29.3 dl	26.0 af	8.3 dg	8.1 jn	7.2 l	8.0 ah
TCL16	25.8 lm	28.9 hm	27.5 hm	27.5 ae	9.6 bg	9.3 em	9.9 ag	9.2 ad
TCL17	30.0 el	29.6 gl	28.3 gl	21.8 eh	9.7 bg	9.5 dm	8.5 el	8.2 ah
TCL18	32.2 bi	36.8 ab	36.0 ab	27.5 ae	11.1 ac	11.2 ae	10.7 ad	8.5 ag
TCL19	37.0 a	41.4 ag	33.8 ag	32.8 a	10.8 ad	10.6 ag	9.4 el	9.8 ae
TCL20	33.6 ae	36.2 ah	33.3 ah	26.4 ae	9.2 cg	7.8 ln	7.7 hl	6.1 hi
TCL21	28.3 hm	35.2 ai	32.9 ai	26.3 ae	10.2 af	11.0 ag	9.1 al	8.7 ag
TCL22	42.3	32.4 ae	34.7 ae	24.4 cg	11.0 ac	11.8 a	10.8 ab	9.1 ah
TCL23	32.1 ci	38.1 a	37.8 a	25.8 ag	10.8 ad	11.4 ac	8.4 el	8.5 ag
TCL24	36.7 ab	37.3 ab	36.0 ab	29.0 ae	10.9 ad	11.2 ad	10.2 ae	8.3 ah
TCL25	33.2 ag	39.5 ag	33.7 ag	29.0 ae	11.5 ac	11.7 ab	9.8 ag	9.2 ad
TCL26	35.2 ad	36.7 cl	29.8 cl	27.8 ae	10.8 ad	10.4 ag	9.9 af	10.2

TCL27	32.8 ah	37.1 ad	35.3 ad	30.4 ac	7.3 gh	10.3 ah	8.3 el	7.8 bi
TCL28	30.1 el	37.4 ac	35.6 ac	32.4 ab	7.6 fh	9.7 ck	9.2 ak	7.1 di
TCL29	28.8 fm	36.3 bk	31.3 bk	23.2 cg	9.2 cg	9.9 aj	8.8 bl	6.5 fi
TCL30	24.6 m	32.2 ak	32.0 ak	28.7 ae	10.3 ae	8.4 in	9.2 al	7.3 ci
TCL31	25.1 m	30.0 bl	30.0 bl	23.0 cg	9.3 bg	10.0 ai	9.0 bl	8.6 ei
TCL32	35.8 ac	31.5 bl	30.3 bl	28.3 ae	9.8 ag	10.6 ag	8.5 el	8.6 ag
TCL33	28.7 gm	30.9 el	28.9 el	24.5 cg	9.8 ag	9.1 gm	9.2 ak	9.2 ad
TCL34	25.7 lm	29.8 fl	28.4 fl	30.3 ad	10.2 af	9.9 bj	9.8 ag	7.5 bi
TCL35	26.6 jm	29.1 km	26.0 km	22.7 dg	10.8 ad	10.7 ag	10.8 ac	9.3 ad
TCL36	28.7 gm	29.5 im	27.0 im	25.7 ag	9.8 ag	9.9 aj	11.2 a	8.8 af
TCL37	27.7 im	33.2 im	27.0 im	26.3 ae	11.1 ac	11.0 ag	9.2 al	9.7 ab
TCL38	26.7 jm	27.7 jm	26.2 jm	21.4 eh	11.0 ac	11.1 af	10.8 ac	9.5 ac
TCL39	30.7 dk	30.0 el	29.0 el	24.8 bg	10.7 ad	10.6 ag	9.8 ag	7.3 ci
B40	15.3 n	19.3 n	19.1 n	15.5 h	5.7 h	5.0	5.3	4.8 i
Mean	29.31	32.56	30.43	26.06	9.74	9.74	9.06	7.95
Prob.	S ***; L***; S x L***				S ***; L***; S x L ns			

S: NaCl; L: Lines; SxL: NaCl x Lines; * significant <0.05; **significant<0.01; ***significant<0.001; ns: non-significant. Means values followed by the same letter in each column indicate non-significant differences.

Appendix 4. Mean value for Biomass/plant at maturity in 39 triticale lines and one cultivar of barley.

Entry	Biomass g/plant				TKW /g/			
	T0	T100	T150	T200	T0	T100	T150	T200
TCL1	10.1 cg	7.0 b	6.0 bc	2.2 jk	37.0 fn	30.7 k	21.2 i	19.8 n
TCL2	10.6 bg	9.5 ab	7.0 bc	3.0 ik	38.8 dl	30.7 hj	26.8 i	21.5em
TCL3	14.5 ae	9.0 ab	7.3 b	4.7 ek	43.7 ch	31.7 ai	28.0 ae	17.5 io
TCL4	14.7 ad	10.8 ab	7.7 bc	7.1 af	38.8 dl	26.0 bj	17.5 di	17.0dm
TCL5	9.9 fg	9.1 ab	4.7 c	3.2 hk	43.2 ci	40.5 jk	26.3 gi	22.5 dk
TCL6	12.1 ag	11.3 ab	7.3 bc	5.2 ck	42.7 cj	36.5 bj	29.2 bh	27.3 a
TCL7	10.8 bg	10.5 ab	8.1 bc	3.7 gk	32.0 kp	31.8 ai	27.2 af	25.3 di
TCL8	13.6 ag	9.0 ab	9.5 bc	6.8 ag	50.5 ac	45.8 ad	35.7 bh	33.0 ac
TCL9	10.2 cg	13.7 ab	6.3 bc	4.3 ek	38.3em	24.8 cj	21.7 bh	20.3 gn
TCL10	10.1 dg	8.5 ab	9.6 bc	7.6 ae	39.0 dl	34.0 dj	30.3 ag	29.3 lo
TCL11	14.3 af	9.9 ab	9.5 bc	5.1 ck	48.5 bd	26.3 bj	31.0 ab	17.8 io
TCL12	12.1 ag	11.6 ab	8.8 bc	6.3 ai	36.2 p	34.5 ae	28.0 ad	29.5 bd
TCL13	13.2 ag	15.2 a	9.4 bc	8.8 ab	41.5 ck	43.3 a	34.2 hi	30.0 ch
TCL14	11.1 bg	10.6 ab	7.4 bc	6.1 bi	46.8 be	40.5 ac	36.3 ag	34.0fm
TCL15	11.5 ag	15.1 a	6.7 bc	6.6 ah	44.7 bg	34.3 ae	23.3 bh	12.8 no
TCL16	13.1 ag	10.8 ab	10.8 bc	9.6 a	34.8 hp	35.3 ae	27.0 af	26.5 ab
TCL17	16.0 a	15.8 a	9.3 bc	5.1 ck	43.5 ch	34.2 ae	25.7 ag	25.3 di
TCL18	11.9 ag	11.6 ab	8.4 bc	3.6 gk	42.3 cj	35.3 bj	29.5 ab	19.3 go
TCL19	11.4 ag	10.0 ab	6.5 bc	6.4 ek	46.7 bf	40.8 bi	35.2 ab	32.3 gn
TCL20	14.9 ab	9.8 ab	8.6 bc	4.3 ek	43.0 ci	33.8 af	35.0 a	15.8 jo
TCL21	12.8 ag	14.2 ab	7.5 bc	6.3 ai	33.7 ip	30.3 ej	23.2 bh	14.5 ko
TCL22	13.9 ag	12.3 ab	9.6 bc	8.8 ab	42.3 cj	39.0 bj	32.5 ac	30.3 gn

TCL23	10.6 bg	11.8 ab	4.6 c	4.9 dk	35.7 go	30.5 bj	24.7 ag	19.3 go
TCL24	10.0 eg	11.8 ab	6.2 bc	3.7 gk	47.0 be	32.2 ah	23.8 bh	23.5 dj
TCL25	13.7 ag	11.0 ab	7.7 bc	4.6 ek	34.5 hp	30.2 bj	27.5 af	17.3 io
TCL26	12.2 ag	10.9 ab	8.8 bc	7.2 ae	52.8 ab	48.0 ab	40.0 bh	39.8 gn
TCL27	10.3 bg	11.7 ab	5.2 c	3.8 fk	33.0 jp	28.8 bj	21.2 bh	18.3 ho
TCL28	13.9 ag	9.9 ab	6.6 bc	3.2 hk	36.3 gn	30.2 bj	27.8 bh	23.0 cg
TCL29	9.5 g	12.2 ab	4.4 c	1.9 k	38.5 np	33.2 ag	25.8 bh	21.3 di
TCL30	9.8 fg	7.5 b	7.6 bc	5.5 bj	35.8mp	33.2 bj	28.5 ac	24.0 ce
TCL31	15.9 a	15.8 a	10.5 bc	8.8 ab	42.7 cj	39.3 bj	35.0 ae	32.8 no
TCL32	10.5 bg	11.6 ab	7.9 bc	6.4 ah	40.7 dl	40.0 fj	38.3 ab	35.8 bd
TCL33	13.9 ag	11.3 ab	7.5 bc	7.6 ae	38.2em	35.0 ae	30.5 ab	27.3 io
TCL34	10.7 bg	10.6 ab	11.6 ac	5.3 cj	36.2 gn	34.5 ae	24.8 ag	22.3 dl
TCL35	12.8 ag	13.6 ab	13.8 ab	8.1 ad	43.0 ci	37.2 bj	30.7 ci	27.5 io
TCL36	14.8 ac	8.7 ab	12.4 ac	5.3 cj	43.7 bh	39.8 ik	30.0 ae	29.3 go
TCL37	10.2 cg	13.5 ab	13.6 ab	8.3 ac	58.7 a	50.7 gi	38.3 bh	34.0mo
TCL38	11.0 bg	13.5 ab	11.2 bc	6.0 bi	38.8 lp	36.3 bj	31.3 ab	28.3 cf
TCL39	13.6 ag	12.2 ab	10.9 bc	4.9 dk	33.2 jp	30.5 bj	27.5 af	18.5 ho
B40	10.4 bg	10.1 ab	5.8 c	5.1 cj	35.8mp	30.0 bj	26.2 ag	18.5 ho
Mean	12.4	11.8	8.5	5.3	39.5	28.8	24.7	21.5
Prob.	S***; L***; S x L*				S***; L***; S x L***			

S: NaCl; L: Lines; SxL: NaCl x Lines; * significant <0.05; **significant<0.01; ***significant<0.001; ns: non-significant. Means values followed by the same letter in each column indicate non-significant differences.

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