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Salt tolerance in barley originating from harsh environment of North Africa

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Abstract

Soil salinity is a major abiotic stress in worldwide agriculture. This has incited a quest towards with an aim of improving the crop plants. An insight into the diversity of barley landraces for salinity tolerance will facilitate their use in genetic improvement and breeding programs. Three gene pools representative of *Hordeum vulgare* L. grown in the North African region and collected from Tunisia, Algeria and Egypt were evaluated at the reproductive stage under non saline and two saline conditions (0, 100 and 200 mM NaCl). A total of 26 agronomic, morphological and yield-related traits were examined by analysis of variance. A significant genetic variation was observed. We successfully identified a set of accessions originating from severe agroclimatic conditions including Tozeur2, Tichedrett, Kerkena and Kebelli2 which remaining the most productive at high salinity having around 4 g grain yield production per plant and about 11 g whole plant dry weight per plant. Cluster analysis and principal component analysis were performed using salt tolerance index (STI), which provided a clear separation of barley landraces. The first three principal components (PC) contributed 64.05% and 66.01% of the variability amongst genotypes at moderate and high salinity level, respectively, with PC1 comprising yield-related traits. Significant number of highly salt tolerant genotypes grouping Early1, Tichedrett, Azrir and Giza125 from North African harsh environment was identified. Data indicate that specific barley genotypes showing differential responses against salinity could be useful as potential germplasm sources for comparative genomic studies and future breeding programs.

Keywords: *Hordeum vulgare*; grain yield; morphological traits; multivariate analysis; salinity; salt tolerance index.
Abbreviations: PCA_Principal Component Analysis; STI_Salt Tolerance Index; TKW_Thousand Kernel Weight.

Introduction

Salinity is one of the major factors limiting plant growth and productivity worldwide, and affects about 7% of the world's total land area (Flowers et al., 1997). This constraint is mostly due to low rainfall in the Mediterranean Basin and is largely aggravated by soil properties, unsuitable irrigation practices, poor drainage, and high levels of evaporation in these regions. North African region is mainly desert with narrow bands of semi arid and arid climate where saline soils are prevalent (Trenberth et al., 2007). To overcome the salinity, a number of strategies have been explicitly reviewed in the literature including reclamation of salt-affected soils which is a very expensive process involving the exogenous application of various inorganic/ organic compounds or plant growth regulators (Munns and Tester, 2008; Ashraf and Akram, 2009; Shahbaz et al., 2012). One of the best alternatives is based on biotic approaches like the use or production of highly salt-tolerant plants (Shahbaz and Ashraf, 2013). Although scientists have succeeded to some extent in improving cereal stress tolerance (Slafer et al., 1999; Araus et al., 2002), there is a big potential to enhance this character thorough biotic means. Soil salinity affects plant growth and grain yield in cereals by reducing tillering capacity, number of spikes per plant, number of spikelets per spike, and number of kernels per spike (Javed et al., 2003; El-Hendawy et al., 2005). Several studies have shown that barley genotypes have a wide genetic variation alongside a high tolerance to salinity (Munns et al., 2002; Qiu et al., 2011). These varietal differences in salt tolerance revealed by morphologically-based screenings can be further investigated in order to better exploit appropriate salt tolerance traits (Noble and Rogers 1992; Ashraf 1994; El-Hendawy et al., 2009). In cereal, this tolerance is stage-dependent and crucially important at the reproductive phase which is the ultimate stage of the plant development and agronomic yield (Francois and Kleiman, 1990; Akram et al., 2002). During plant development, different barley genotypes exhibit a substantial variation in various parameters during the tillering, booting and grain filling phases which are physiologically important growth stages contributing to good yield production (Ahmad et al., 2003) since grain yield is considered to be the most direct criterion for assessing responses to salinity in cereals (Shannon, 1997). Success has already been achieved using multivariate analysis based on agro-morphological parameters intended for ranking genotypes for salt tolerance (Shannon, 1997; Zeng et al., 2002). Cluster and Principal Component Analysis (PCA) have been used in barley as a powerful tool for population grouping and screening of huge number of accessions in terms of salt (Jaradat et al., 2004) or drought tolerance (Eivazi et al., 2013). Such approaches were investigated on barley (Jaradat et al., 2004; Afuape et al., 2011), but to date no works report the use of Salt Tolerance Index (STI) of multiple morphological parameters to evaluate barley at reproductive stage against salt stress. There are only a few reports of the application of biotic approaches to increase salt tolerance in barley (Shahbaz and Ashraf, 2013). As is already known, genotypes coming from salty soils have much more tolerance toward the salinity stress (Bayuelo-Jimennez et al., 2002; Munns et al., 2002; Zeng et al., 2002). The use of accessions originating from harsh environments may yield an undoubtedly rich genetic potential against salinity. Many sources of salt tolerance in barley must be identified to broaden the gene pool and provide donor parents in locally adapted genetic backgrounds. There is a lack of data regarding barley salt tolerance during the reproductive phase, since grain yield is the key target of breeding programs. This study aims to investigate the levels and patterns of genetic diversity among North African barley landraces using multiple morphological and yield parameters in order to conserve and exploit germplasm efficiently face to salinity.

Results

Growth and yield response of barley genotypes to salinity

Assessments of vegetative and reproductive traits showed considerable variations among barley accessions in all traits under normal and both moderate and high saline conditions (100 and 200 mM NaCl respectively) as illustrated in Fig 1. In this study, data showed that salinity generally suppressed total plant biomass and vegetative traits (shoot dry weight per plant, leaf and tiller number per plant) in the majority of barley genotypes, except in accessions Giza125 and Giza130 that exhibited increases at moderate salinity levels (Fig. 1).

Furthermore, results revealed a great number of genotypes with high vigor for grain yield and plant growth under normal and saline conditions. On the basis of growth performance, the highest values of total plant biomass and vegetative traits studied were recorded for the Tozeur2 accession at non salinized conditions, and for the Temacine accession in moderately saline conditions; however both Tozeur2 and Tichedrett accessions showed better growth performance in high salinity levels (Fig. 1). Adversely, Early1 showed the lowest values of these traits in all treatments (0, 100 and 200 mM NaCl). Concerning grain yield and its components performance, Kebilli2 was the most productive under non salinized condition. At 100 mM NaCl, Giza125 and Giza126 performed higher grain yield production and grain number per plant, while Tozeur1 and Temacine had the highest number of spike per plant. Early1 and Early2 produced the least grain yield (Fig. 2). When the grain yield and its related traits performance of all the 31 genotypes was taken into consideration at high salinity, significantly higher values of these traits were recorded for Tozeur2, Tichedrett, Kerkena and Kebilli2; while El Arich was the least productive at increasing salinity (Fig. 2). Thousand- kernel weight (TKW) (g) was not affected in majority of genotypes. For instance, it was unchanged in Rihane, Ras El mouche and Early1 at high salinity. Data showed that maximum value of TKW was recorded for Ksar Megarine in non-salinized condition and for Giza130 and Giza123 at 100 and 200 mM NaCl, respectively. However, Tombari had the lowest value under both saline levels.

Variation in salinity tolerance using salt tolerance index

For better evaluation of 31 barley genotypes for salinity tolerance, salt tolerance index (STI) was used. High genetic diversity for salinity tolerance of growth and reproductive traits was observed in North African barley. For instance, at 200 mM NaCl, STI for shoot dry weight ranged from 126.56% (in Azrir) to 38.2% (in El Arich), STI for root dry weight ranged from 92.61% (in Temacine) to 26.64% (in Giza 130) and STI for grain yield ranged from 106.11% (in Saida) to 21.34% (in El Arich). Globally, STI of almost all morphological traits studied decreased with increasing salinity (Table 1). Whole plant dry weight, leaf number, tiller number, shoot and root dry weight were the most severely affected growth traits, while grain number and spike number per plant were the mostly affected among reproductive traits under 200 mM NaCl. In this way, Early1, Tichedrett, Sidi Mahdi and Azrir acquired the maximum STI for whole plant dry weight (STI≃ 100%) at 200 mM NaCl (Table 1.a.c). In contrast, Giza2000 and El Arich showed the minimum STI for this trait (STI ≃ 40%). Based on STI of grain yield, genotypes Giza125 and Giza130 were identified as the most tolerant under 100 mM NaCl (STI 166.42% and 121.09% respectively), whereas Sidi Mahdi was the most sensitive (STI of grain yield= 50.47%) as shown in Table1.b.c. Furthermore, results showed that the most salt tolerant individuals based on STI of grain yield at high salinity level were Saida, Early1, Tichedrett, Azrir and Giza125 having STI≃100%. In the other hand, Giza2000 (STI=31.59%) and El Arich (STI=21.34%) displayed the most sensitive (Table 1.b). In some cases, STI showed that less tolerant barley genotypes (such as Tozeur2, Kebilli 2 and Kerkena) showed much better performance of grain yield production than the more tolerant cultivars (such as Early1and Azrir) under high salt stress level.

Salt tolerance index-based cluster analysis

Based on various phenotypic data, genotypes were grouped by their salt tolerance index at 100 and 200 mM NaCl on the basis of Euclidean distances of dissimilarity (Fig. 3). Under moderate salinity, barley genotypes were classified into three clusters (Fig. 3-a). Cluster II contained eleven tolerant genotypes (high STI for grain yield), whereas Cluster I and Cluster III included mainly moderately tolerant accessions. The greatest number of accessions (17) was in Cluster I, while Cluster III comprised only three accessions. Furthermore, the first cluster containing the majority of Tunisian and Egyptian accessions was more attached to the third cluster. Under high salinity level, cluster analysis categorized genotypes also into three groups (Fig. 3-b). Cluster I and Cluster II grouped together highly salt tolerant and moderately tolerant genotypes, while Cluster III included only salt susceptible accessions. Cluster I contained the majority of accessions (13 genotypes) and it was the nearest to Cluster II (10 genotypes). Most of Tunisian and Egyptian genotypes were included in Cluster I and Cluster II respectively, whereas, equal proportions of Algerian genotypes were found in the 3 clusters.

Principal component analysis (PCA)

Genotypic variation for the salt tolerance index was explained clearly and concisely by Principal Component Analysis (PCA) in 31 barley genotypes (Table 2). PCA revealed that the first three principal components (PC) explained 64.05% and 66.01% of the total variation at moderate and high salinity level, respectively. The first component (PC1) accounted for 29.6% and 31.4% of the variation at 100 and 200 mM NaCl, respectively and had high positive coefficients with STI of grain yield, grain number and total spikes dry weight per plant at both levels of stress (Table 2). Thus, the PC1 was named as salt tolerance in terms of grain yield and detached high tolerant genotypes. The second component (PC2) accounted for 24.3% and 21.6% of the observed variation at 100 and 200 mM NaCl,

Table 1. Salt tolerance index (± standard error) of vegetative traits (a), yield related traits (b) and calculated ratio of morphological traits (c) for 31 barley genotypes under 100 and 200 mM NaCl.

	a. Vegetative traits											
	WDW (g)		ShDW (g)		RDW (g)		PH (cm)		TN (n)		LN (n)	
Genotypes	STI 100	STI 200	STI 100	STI 200	STI 100	STI 200	STI 100	STI 200	STI 100	STI 200	STI 100	STI 200
Kebelli 2	75.86 $^{g-k}$ ±1.44	61.98 $^{c-h}$ ±4.83	90.32 $^{d-h}$ ±3.52	67.87 $^{d-g}$ ±5.13	67.28 $^{e-i}$ ±6.54	58.76 $^{e-j}$ ±5.52	106.50 ^{b} ±2.95	94.92 $^{a-e}$ ±1.47	80.85 $^{g-j}$ ±2.81	74.47 $^{a-f}$ ±3.84	84.69 $^{e-i}$ ±3.58	66.42 $^{c-g}$ ±3.28
Tozeur 2	66.31 $^{j-l}$ ±1.94	59.36 $^{c-i}$ ±5.09	49.53 ^{k} ±6.40	54.36 $^{f-i}$ ±6.41	87.48 $^{b-e}$ ±9.74	55.36 $^{e-k}$ ±7.76	88.10 $^{g-i}$ ±4.25	79.12 $^{j-l}$ ±1.18	63.83 ^{j} ±6.38	78.72 $^{a-f}$ ±8.71	80.72 $^{e-i}$ ±6.37	85.24 $^{a-e}$ ±11.35
Rihane	92.50 $^{d-g}$ ±4.60	44.97 $^{h-j}$ ±2.29	88.72 $^{d-h}$ ±5.78	49.28 $^{g-i}$ ±3.41	79.39 $^{c-g}$ ±8.46	68.27 $^{b-f}$ ±5.25	98.67 $^{b-d}$ ±1.72	83.58 $^{h-j}$ ±1.29	87.18 $^{f-j}$ ±7.48	64.10 $^{c-g}$ ±5.13	89.37 $^{d-h}$ ±8.54	89.70 $^{a-c}$ ±5.94
Manel	97.69 $^{d-f}$ ±2.97	61.70 $^{c-h}$ ±4.34	105.67 $^{b-d}$ ±7.07	62.33 $^{e-h}$ ±5.27	55.87 $^{g-j}$ ±4.96	37.90 ^{kl} ±2.85	93.86 $^{d-h}$ ±2.59	85.14 $^{f-j}$ ±2.28	135.71 ^{b} ±12.88	92.86 ^{ab} ±8.38	153.96 ^{a} ±13.49	103.96 ^{a} ±11.76
Jerba	87.27 $^{e-h}$ ±7.24	51.87 $^{d-j}$ ±2.28	97.14 $^{c-g}$ ±6.85	55.75 $^{f-i}$ ±3.85	63.31 $^{e-j}$ ±5.81	54.05 $^{e-k}$ ±4.54	98.82 $^{b-d}$ ±2.76	83.42 $^{h-j}$ ±1.91	93.02 $^{e-i}$ ±7.07	62.79 $^{c-g}$ ±4.93	102.88 $^{c-g}$ ±6.33	71.22 $^{b-f}$ ±8.45
Sidi Bouzid	99.12 $^{d-f}$ ±3.96	70.55 ^{c} ±4.78	88.14 $^{d-h}$ ±5.21	73.58 $^{c-f}$ ±5.90	95.11 $^{b-d}$ ±8.55	52.32 $^{f-k}$ ±4.14	99.37 $^{b-d}$ ±2.30	91.75 $^{c-g}$ ±0.89	96.77 $^{d-i}$ ±8.38	87.10 $^{a-d}$ ±11.85	104.78 $^{c-g}$ ±6.71	96.09 ^{ab} ±11.30
Kairouan	71.01 $^{h-l}$ ±2.82	59.44 $^{c-i}$ ±4.18	59.00 $^{i-k}$ ±2.54	59.27 $^{e-i}$ ±6.74	72.40 $^{c-h}$ ±7.28	45.11 $^{h-l}$ ±4.97	89.86 $^{f-i}$ ±0.41	84.66 $^{f-j}$ ±2.21	92.86 $^{e-i}$ 6.19	69.05 $^{b-g}$ ±7.81	90.99 $^{d-h}$ ±8.59	74.22 $^{b-f}$ ±10.96
Gabès	100.99 ^{de} ±6.06	70.71 ^{c} ±6.53	104.51 $^{b-d}$ ±6.64	72.10 $^{d-f}$ ±6.46	54.76 $^{g-j}$ ±7.37	46.23 $^{g-k}$ ±6.52	95.95 $^{c-g}$ ±1.89	83.95 $^{g-j}$ ±3.55	125.71 $^{b-d}$ ±5.15	88.57 $^{a-c}$ ±7.56	108.24 $^{c-f}$ ±7.90	83.87 $^{a-e}$ ±8.98
Tozeur 1	87.28 $^{e-h}$ ±5.62	48.10 $^{f-j}$ ±3.21	98.53 $^{c-g}$ ±8.36	65.80 $^{e-g}$ ±7.26	75.57 $^{c-g}$ ±6.06	36.26 ^{kl} ±4.68	83.94 ^{ij} ±1.75	73.52 ^{l} ±1.70	119.05 $^{b-e}$ ±8.83	69.05 $^{b-g}$ ±5.95	104.29 $^{c-g}$ ±8.49	62.71 $^{c-g}$ ±8.07
Tombari	83.92 $^{e-j}$ ±4.05	62.83 $^{c-g}$ ±4.03	116.69 $^{a-c}$ ±9.90	71.02 $^{d-g}$ ±4.91	86.47 $^{b-f}$ ±8.12	61.87 $^{d-j}$ ±2.99	92.52 $^{d-h}$ ±2.02	91.17 $^{c-h}$ ±1.92	164.29 ^{a} ±13.60	85.71 $^{a-e}$ ±7.58	140.52 ^{ab} ±8.89	53.90 ^{fg} ±6.77
Kerkena	86.24 $^{e-i}$ ±4.98	62.46 $^{c-g}$ ±3.98	100.87 $^{c-f}$ ±5.81	57.06 $^{f-i}$ ±4.44	59.18 $^{f-j}$ ±6.75	46.79 $^{g-k}$ ±2.00	106.47 ^{b} ±3.76	96.21 $^{a-d}$ ±2.45	124.32 $^{b-d}$ ±9.46	89.19 $^{a-c}$ ±5.73	104.94 $^{c-g}$ ±8.19	78.20 $^{a-f}$ ±7.52
Sidi Mahdi	102.32 ^{de} ±5.54	100.07 ^{ab} ±6.62	116.60 $^{a-c}$ ±8.22	101.06 ^{b} ±8.79	106.40 ^{b} ±11.28	83.13 $^{a-c}$ ±9.78	79.05 ^{j} ±2.39	79.05 $^{j-l}$ ±0.26	121.05 $^{b-e}$ ±7.33	89.47 $^{a-c}$ ±11.01	95.00 $^{d-h}$ ±5.27	62.39 $^{c-g}$ ±9.90
Ras El Mouche	80.58 ±10.59	69.85 ^{c} ±3.66	92.18 $^{d-h}$ ±9.42	80.53 $^{c-e}$ ±8.05	70.17 $^{c-h}$ ±7.45	79.69 $^{a-d}$ ±6.62	89.74 $^{f-i}$ ±1.10	86.66 $^{f-j}$ ±1.77	85.29 $^{f-j}$ ±10.60	82.35 $^{a-f}$ ±6.90	68.26 ^{hi} ±5.27	59.94 $^{d-g}$ ±2.65
Ksar Megarine	86.24 $^{e-i}$ ±2.66	89.04 ^{b} ±2.78	77.49 $^{f-j}$ ±6.43	93.78 ^{bc} ±5.30	63.86 $^{e-j}$ ±7.14	86.09 ^{ab} ±5.15	84.11 ^{ij} ±1.95	85.44 $^{f-j}$ ±1.99	100.00 $^{c-h}$ ±10.94	96.77 ^{a} ±9.68	89.03 $^{d-h}$ ±5.64	86.21 $^{a-d}$ ±4.63
Saida	89.53 $^{e-h}$ ±5.30	69.01 ^{cd} ±6.70	75.66 $^{g-j}$ ±5.01	65.32 $^{e-g}$ ±6.26	76.17 $^{c-g}$ ±6.41	43.30 $^{i-l}$ ±3.49	99.35 $^{b-d}$ ±1.42	95.81 $^{a-d}$ ±2.36	110.71 $^{b-f}$ ±7.78	82.14 $^{a-f}$ ±7.78	108.96 $^{c-e}$ ±3.91	73.48 $^{b-f}$ ±7.93
Azrir	125.66 ^{bc} ±8.76	96.30 ^{ab} ±6.78	132.20 ^{a} ±10.79	126.56 ^{a} ±10.01	96.90 ^{bc} ±16.49	65.98 $^{c-g}$ ±5.66	95.33 $^{c-g}$ ±0.76	86.73 $^{f-j}$ ±2.65	121.05 $^{b-e}$ ±8.32	89.47 $^{a-c}$ ±9.49	127.59 ^{bc} ±10.25	83.45 $^{a-e}$ ±9.08
Rihane 03	67.28 $^{i-l}$ ±4.32	46.74 $^{g-j}$ ±1.75	69.06 $^{h-k}$ ±5.70	55.61 $^{f-i}$ ±1.94	40.20 ^{ij} ±3.31	53.38 $^{e-k}$ ±6.11	103.66 ^{bc} ±4.13	92.54 $^{b-f}$ ±1.65	76.92 $^{h-j}$ ±6.66	64.10 $^{c-g}$ ±5.13	86.05 $^{d-i}$ ±6.52	62.61 $^{c-g}$ ±2.56
Tichedrette	111.11 ^{cd} ±5.22	102.19 ^{ab} ±4.44	98.33 $^{c-g}$ ±8.16	93.17 ^{bc} ±9.91	52.10 $^{g-j}$ ±3.17	49.91 $^{f-k}$ ±2.26	90.32 $^{e-i}$ ±0.85	87.37 $^{e-i}$ ±3.43	117.65 $^{b-e}$ ±8.95	94.12 ^{ab} ±7.78	108.21 $^{c-f}$ ±6.71	80.06 $^{a-f}$ ±6.90
Nailia	62.73 $^{k-m}$ ±3.24	38.20 ^{j} ±4.62	71.44 $^{h-k}$ ±5.02	52.47 $^{f-i}$ ±8.21	38.78 ^{j} ±4.85	50.12 $^{f-k}$ ±6.79	86.97 ^{hi} ±2.94	78.79 $^{j-l}$ ±2.74	78.26 $^{g-j}$ ±5.65	36.96 ^{h} ±6.05	83.28 $^{e-i}$ ±4.00	54.33 ^{fg} ±9.27
Temacine	97.83 $^{d-f}$ ±3.74	50.44 $^{e-j}$ ±2.71	106.49 $^{b-d}$ ±4.17	53.09 $^{f-i}$ ±5.70	142.08 ^{a} ±9.94	92.61 ^{a} ±8.95	118.05 ^{a} ±2.69	90.08 $^{c-i}$ ±3.23	129.55 ^{bc} ±9.02	88.64 $^{a-c}$ ±6.82	104.59 $^{c-g}$ ±4.62	76.76 $^{b-f}$ ±4.10
Early 1	104.38 ^{de} ±15.08	108.88 ^{a} ±12.67	103.58 $^{b-e}$ ±14.26	123.25 ^{a} ±13.67	68.56 $^{d-h}$ ±15.04	72.74 $^{b-e}$ ±4.03	98.20 $^{b-e}$ ±4.86	100.16 ^{ab} ±2.92	78.57 $^{g-j}$ ±12.11	60.71 $^{d-h}$ ±11.29	105.76 $^{c-g}$ ±18.19	66.19 $^{c-g}$ ±9.99
Early 2	56.68 ^{lm} ±6.01	56.86 $^{c-i}$ ±4.01	61.81 $^{i-k}$ ±7.07	63.59 $^{e-h}$ ±3.74	55.30 $^{g-j}$ ±8.64	62.77 $^{d-i}$ ±9.98	85.86 $^{h-j}$ ±2.23	92.67 $^{b-f}$ ±1.80	62.79 ^{j} ±11.57	60.47 $^{d-h}$ ±2.33	59.77 ^{i} ±7.62	53.52 ^{fg} ±3.96
Giza 123	77.23 $^{g-k}$ ±4.88	58.98 $^{c-i}$ ±4.76	80.43 $^{e-i}$ ±7.18	65.53 $^{e-g}$ ±5.31	77.97 $^{c-g}$ ±6.67	45.33 $^{h-l}$ ±6.84	98.92 $^{b-d}$ ±2.32	100.72 ^{a} ±2.66	97.06 $^{d-i}$ ±11.67	67.65 $^{b-g}$ ±7.78	130.00 $^{a-c}$ ±11.59	84.00 $^{a-e}$ ±7.15
Giza 125	144.94 ^{a} ±10.60	90.36 ^{b} ±5.45	130.07 ^{a} ±6.50	87.60 $^{b-d}$ ±4.61	67.20 $^{e-i}$ ±5.96	60.48 $^{d-j}$ ±5.50	103.20 ^{bc} ±1.52	102.00 ^{a} ±1.77	102.94 $^{c-h}$ ±10.29	55.88 $^{f-h}$ ±5.30	113.15 ^{cd} ±8.06	66.53 $^{c-g}$ ±5.45
Giza 126	98.24 $^{d-f}$ ±3.44	60.96 $^{c-h}$ ±4.02	88.66 $^{d-h}$ ±3.74	59.36 $^{e-i}$ ±4.40	88.56 $^{b-e}$ ±7.64	47.84 $^{g-k}$ ±6.14	93.98 $^{d-h}$ ±2.13	82.61 $^{i-k}$ ±4.69	107.41 $^{b-g}$ ±4.90	92.59 ^{ab} ±4.90	96.90 $^{d-g}$ ±4.06	57.75 $^{e-g}$ ±5.36
Giza 127	86.14 $^{e-i}$ ±2.90	64.65 $^{c-f}$ ±2.54	91.47 $^{d-h}$ ±3.60	71.08 $^{d-g}$ ±5.05	56.06 $^{g-j}$ ±5.05	61.76 $^{d-j}$ ±7.96	100.78 $^{b-d}$ ±3.64	97.32 $^{a-c}$ ±1.81	108.00 $^{b-g}$ ±6.00	92.00 ^{ab} ±6.32	80.08 $^{f-i}$ ±7.38	85.44 $^{a-d}$ ±7.01
Giza 129	93.85 $^{d-g}$ ±5.93	67.26 $^{c-e}$ ±6.52	96.15 $^{c-g}$ ±6.88	70.86 $^{d-g}$ ±7.11	63.88 $^{e-j}$ ±7.45	63.76 $^{d-h}$ ±3.44	97.54 $^{c-f}$ ±1.46	91.48 $^{c-h}$ ±1.48	124.14 $^{b-d}$ ±8.96	82.76 $^{a-f}$ ±13.68	96.40 $^{d-g}$ ±5.91	64.75 $^{c-g}$ ±11.61
Giza 130	136.82 ^{ab} ±4.86	62.59 $^{c-g}$ ±7.55	125.63 ^{ab} ±6.54	63.28 $^{e-h}$ ±9.23	47.86 $^{h-j}$ ±3.83	26.64 ^{l} ±4.72	98.40 $^{b-e}$ ±1.39	84.80 $^{f-j}$ ±3.85	163.64 ^{a} ±9.64	81.82 $^{a-f}$ ±13.64	153.44 ^{a} ±10.31	69.84 $^{b-f}$ ±10.68
Giza 131	92.20 $^{d-g}$ ±4.18	62.84 $^{c-g}$ ±2.48	90.29 $^{d-h}$ ±6.99	60.52 $^{e-h}$ ±2.33	54.42 $^{g-j}$ ±6.81	63.22 $^{d-i}$ ±5.26	86.64 $^{h-j}$ ±2.34	86.03 $^{f-j}$ ±2.30	85.71 $^{f-j}$ ±5.36	78.57 $^{a-f}$ ±5.65	95.31 $^{d-h}$ ±6.32	75.00 $^{b-f}$ ±5.50
Giza 2000	46.74 ^{m} ±3.31	38.48 ^{j} ±3.28	56.63 ^{jk} ±5.80	42.61 ^{hi} ±4.96	60.00 $^{f-j}$ ±6.17	42.14 $^{j-l}$ ±5.77	98.21 $^{b-e}$ ±1.99	89.29 $^{d-i}$ ±2.69	70.27 ^{ij} ±4.87	43.24 ^{gh} ±6.76	77.63 $^{g-i}$ ±6.04	41.70 ^{g} ±7.64
El Arich	86.08 $^{e-i}$ ±6.35	43.40 ^{ij} ±4.83	76.35 $^{g-j}$ ±6.24	38.20 ^{i} ±3.59	85.30 $^{b-f}$ ±9.12	69.93 $^{b-f}$ ±5.95	92.41 $^{d-h}$ ±0.92	75.64 ^{kl} ±1.62	97.44 $^{d-i}$ ±10.73	58.97 $^{e-h}$ ±5.59	99.66 $^{d-g}$ ±9.56	53.45 ^{fg} ±5.73
Total Mean	90.15	65.52	91.60	69.54	71.24	57.54	95.31	88.15	103.94	76.14	101.43	71.71
Std. Error of Total Mean	±1.60	±1.40	±1.72	±1.64	±1.84	±1.34	±0.63	±0.59	±2.12	±1.63	±1.89	±1.59

Table 1. Continued from previous page.

b. Yield related traits

	GY (g)		SDW (g)		1SDW (g)		SN (n)		GN/P (n)		StN (n)		GN/S (n)		AL (cm)		RL (cm)		SL (cm)		TKW (cm)	
Genotypes	STI 100	STI 200	STI 100	STI 200	STI 100	STI 200	STI 100	STI 200	STI 100	STI 200	STI 100	STI 200	STI 100	STI 200	STI 100	STI 200	STI 100	STI 200	STI 100	STI 200	STI 100	STI 200
Kebelli 2	81.29^{g-j} ±4.09	55.05^{f-l} ±5.47	83.15^{d-h} ±1.37	71.77^{d-f} ±6.80	73.61^{ij} ±4.33	67.19^{k-m} ±3.89	110.71^{c-g} ±5.65	103.57^{bc} ±8.93	78.61^{j-l} ±3.36	65.73^{h-j} ±4.61	67.03^{f-h} ±3.56	61.29^{j-l} ±4.41	67.03^{f-h} ±3.56	61.29^{j-l} ±4.41	90.63^{f-j} ±3.11	95.04^{e-i} ±1.89	91.76^{i-n} ±3.87	89.56^{e-h} ±3.55	95.39^{f-k} ±1.10	92.88^{hi} ±2.45	78.35^{l-n} ±1.46	70.92^{i} ±1.62
Tozeur 2	65.05^{i-l} ±5.14	65.11^{e-i} ±4.68	77.65^{f-i} ±2.15	71.04^{d-f} ±5.66	113.42^{b-e} ±7.79	104.89^{c-e} ±5.31	68.42^{ij} ±4.74	65.79^{e-i} ±5.26	80.64^{i-l} ±1.80	72.18^{d-i} ±2.17	114.42^{a-d} ±9.39	107.46^{c-j} ±9.63	114.42^{a-d} ±9.39	107.46^{c-j} ±9.63	97.82^{cd} ±1.74	88.27^{j-l} ±0.57	119.09^{bc} ±5.76	93.83^{c-g} ±1.68	102.76^{b-d} ±0.66	95.92^{gh} ±1.81	93.07^{f-h} ±1.34	80.01^{d-h} ±2.31
Rihane	111.38^{c-e} ±3.95	39.72^{lm} ±2.67	96.85^{c-g} ±4.25	39.00^{ij} ±2.37	95.28^{d-i} ±4.69	50.28^{m} ±5.10	106.67^{d-h} ±7.26	83.33^{c-f} ±6.67	123.79^{b-d} ±5.52	61.42^{ij} ±3.06	112.34^{a-e} ±8.42	72.14^{i-l} ±5.63	112.34^{a-e} ±8.42	72.14^{i-l} ±5.63	96.10^{c-e} ±0.63	92.92^{f-j} ±1.96	92.47^{h-m} ±4.71	81.21^{hi} ±2.72	93.97^{g-k} ±0.98	90.44^{h-j} ±1.13	90.52^{g-i} ±1.62	98.60^{a} ±2.63
Manel	97.70^{d-g} ±8.49	59.11^{e-k} ±4.35	126.84^{b} ±8.08	75.73^{d-f} ±8.12	94.22^{e-i} ±3.83	67.57^{k-m} ±5.04	139.13^{a-c} ±14.74	113.04 ±10.20	105.54^{e-g} ±3.57	71.89^{d-i} ±3.01	77.94^{c-h} ±6.51	64.86^{i-l} ±5.96	77.94^{c-h} ±6.51	64.86^{i-l} ±5.96	106.26^{ab} ±1.24	90.42^{h-l} ±1.96	107.08^{d-f} ±2.97	96.03^{c-f} ±2.02	102.09^{c-e} ±1.73	90.82^{h-j} ±1.71	91.19^{gh} ±2.42	74.35^{f-i} ±3.04
Jerba	97.18^{e-g} ±7.61	64.23^{e-j} ±6.52	92.64^{c-g} ±9.62	53.39^{f-j} ±3.11	93.85^{e-i} ±5.86	87.72^{e-k} ±5.82	97.06^{f-i} ±7.64	61.76^{f-i} ±4.41	103.83^{f-h} ±5.88	69.69^{e-i} ±5.63	105.21^{a-f} ±9.82	106.67^{c-j} ±7.82	105.21^{a-f} ±9.82	106.67^{c-j} ±7.82	96.42^{c-e} ±1.92	104.27^{bc} ±1.66	93.69^{g-m} ±3.75	90.82^{d-h} ±2.95	95.61^{f-j} ±1.66	99.58^{fg} ±1.54	76.28^{mn} ±2.05	78.75^{d-i} ±2.27
Sidi Bouzid	119.73^{b-d} ±6.40	85.16^{b-d} ±4.43	113.58^{bc} ±10.41	79.50^{c-e} ±6.62	115.91^{b-d} ±11.78	96.55^{d-g} ±8.26	104.17^{d-h} ±8.33	91.67^{b-e} ±12.67	125.99^{bc} ±6.30	91.94^{b} ±5.34	120.22^{ab} ±10.41	106.37^{c-j} ±10.84	120.22^{ab} ±10.41	106.37^{c-j} ±10.84	85.94^{j-l} ±1.04	84.37^{l} ±1.41	100.96^{f-j} ±5.46	97.61^{c-e} ±2.06	92.10^{j-m} ±1.54	92.10^{h-j} ±1.84	93.49^{e-h} ±1.05	78.29^{d-i} ±1.63
Kairouan	71.53^{i-l} ±3.92	50.59^{h-l} ±5.66	82.07^{e-h} ±4.79	63.94^{e-h} ±7.31	84.33^{f-i} ±5.46	80.44^{f-l} ±3.28	97.06^{f-i} ±7.64	76.47^{c-h} ±6.90	88.50^{h-k} ±3.13	70.26^{e-i} ±3.33	85.13^{b-g} ±6.44	87.10^{e-k} ±7.99	85.13^{b-g} ±6.44	87.10^{e-k} ±7.99	92.83^{d-g} ±2.36	89.45^{i-l} ±1.07	104.30^{e-g} ±3.29	84.72^{f-h} ±2.49	97.59^{e-i} ±1.64	91.87^{h-j} ±1.03	84.02^{i-l} ±1.40	71.41^{hi} ±0.75
Gabès	107.85^{c-f} ±5.00	54.84^{f-l} ±6.05	107.21^{b-e} ±6.85	74.35^{d-f} ±7.52	77.46^{ij} ±4.23	78.35^{f-l} ±3.04	142.31^{ab} ±10.71	96.15^{b-d} ±9.62	118.65^{c-f} ±6.29	75.12^{c-i} ±4.95	79.07^{c-h} ±3.48	77.22^{g-l} ±7.51	79.07^{c-h} ±3.48	77.22^{g-l} ±7.51	88.65^{g-k} ±1.53	90.38^{h-l} ±0.59	97.06^{f-l} ±2.02	96.10^{c-f} ±4.45	87.38^{no} ±1.88	84.38^{k} ±0.86	82.72^{j-m} ±1.24	52.24^{k} ±2.78
Tozeur 1	97.63^{d-g} ±5.66	51.71^{g-l} ±4.85	90.62^{c-g} ±6.54	44.39^{h-j} ±3.29	81.14^{g-i} ±6.80	72.08^{h-l} ±6.60	121.62^{b-f} ±12.82	67.57^{e-h} ±7.88	93.83^{g-j} ±2.41	49.09^{j-l} ±2.69	82.52^{b-h} ±8.62	79.09^{g-l} ±9.49	82.52^{b-h} ±8.62	79.09^{g-l} ±9.49	81.37^{l} ±1.55	93.59^{f-j} ±1.96	73.15^{o} ±1.81	83.89^{f-h} ±3.77	82.20^{pq} ±1.07	90.37^{h-j} ±0.98	88.90^{h-j} ±3.04	82.47^{c-f} ±3.29
Tombari	76.60^{g-j} ±8.22	45.20^{j-m} ±6.50	71.13^{g-i} ±6.45	57.04^{e-i} ±4.58	59.80^{j} ±3.31	68.15^{k-m} ±3.98	118.52^{b-f} ±8.07	85.19^{c-f} ±8.07	73.11^{k-m} ±2.42	65.68^{h-j} ±4.75	60.10^{g-h} ±3.71	77.77^{g-l} ±8.97	60.10^{gh} ±3.71	77.77^{g-l} ±8.97	87.01^{h-k} ±1.35	88.24^{j-l} ±0.62	86.88^{l-n} ±1.72	88.78^{e-h} ±0.71	90.83^{k-n} ±1.47	88.16^{i-k} ±0.74	80.71^{l-n} ±2.25	60.81^{j} ±4.28
Kerkena	75.54^{g-j} ±6.57	71.42^{d-f} ±3.32	80.70^{e-i} ±5.50	69.38^{d-g} ±4.57	80.20^{h-j} ±7.61	68.51^{k-m} ±3.42	103.03^{e-h} ±9.94	96.97^{b-d} ±4.79	83.94^{i-k} ±1.61	65.14^{h-j} ±4.12	81.37^{b-h} ±10.93	61.37^{j-l} ±4.96	81.37^{b-h} ±10.93	61.37^{j-l} ±4.96	95.69^{c-f} ±1.35	95.11^{e-i} ±1.11	115.57^{cd} ±2.31	93.84^{c-g} ±2.41	92.99^{i-l} ±1.35	91.53^{h-j} ±1.01	81.25^{k-m} ±0.88	78.86^{d-i} ±2.97
Sidi Mahdi	50.47^{l} ±6.58	52.29^{f-l} ±7.32	96.27^{c-g} ±7.12	101.69^{ab} ±10.96	84.26^{f-i} ±5.84	78.23^{f-l} ±2.78	131.58^{a-e} ±10.53	136.84^{a} ±14.65	65.38^{l-n} ±5.51	67.31^{g-i} ±6.46	45.69^{h} ±3.73	48.01^{kl} ±6.36	45.69^{h} ±3.73	48.01^{kl} ±6.36	90.60^{f-j} ±1.43	89.42^{i-l} ±1.17	96.96^{f-l} ±1.86	90.71^{d-h} ±1.43	87.42^{no} ±2.04	88.68^{i-k} ±1.88	74.39^{n} ±1.84	71.93^{g-i} ±2.24
Ras El Mouche	75.02^{g-j} ±8.09	62.90^{e-j} ±6.61	75.64^{f-i} ±13.22	63.41^{e-h} ±6.82	94.97^{d-i} ±5.13	76.91^{g-l} ±3.41	81.82^{g-j} ±10.16	78.79^{c-g} ±8.44	82.33^{i-l} ±4.99	68.11^{f-i} ±6.05	107.19^{a-e} ±14.29	89.14^{d-k} ±11.59	107.19^{a-e} ±14.29	89.14^{d-k} ±11.59	98.30^{c} ±0.65	109.98^{ab} ±3.21	86.12^{mn} ±2.75	88.26^{e-h} ±1.01	100.77^{de} ±0.98	108.51^{bc} ±1.04	102.60^{bc} ±2.68	98.52^{a} ±1.63
Ksar Megarine	77.13^{g-j} ±8.99	70.83^{d-g} ±3.53	79.59^{e-i} ±7.66	78.09^{c-e} ±5.44	73.01^{ij} ±5.82	79.88^{f-l} ±6.68	103.85^{d-h} ±11.54	100.00^{b-d} ±6.93	86.44^{i-k} ±9.19	90.69^{bc} ±12.50	93.10^{a-g} ±17.96	85.97^{e-k} ±9.08	93.10^{a-g} ±17.96	85.97^{e-k} ±9.08	96.78^{c-e} ±0.40	88.23^{j-l} ±1.29	86.09^{mn} ±1.86	72.14^{ij} ±3.22	94.28^{g-k} ±1.60	86.74^{jk} ±1.73	90.21^{g-i} ±0.92	76.66^{e-i} ±3.22
Saida	108.31^{c-f} ±10.94	106.11^{a} ±7.34	100.48^{c-f} ±9.83	79.10^{c-e} ±9.59	105.25^{b-f} ±7.72	92.81^{d-h} ±4.70	96.00^{f-i} ±8.49	84.00^{c-f} ±8.49	103.58^{f-h} ±8.55	108.26^{a} ±5.05	110.25^{a-e} ±13.99	134.44^{b-d} ±13.92	110.25^{a-e} ±13.99	134.44^{b-d} ±13.92	90.74^{f-j} ±0.90	93.73^{f-j} ±1.70	93.43^{h-m} ±2.16	92.09^{d-h} ±3.86	91.28^{j-n} ±1.32	88.97^{i-k} ±1.81	92.20^{f-h} ±3.00	85.64^{b-d} ±2.88
Azrir	135.39^{b} ±8.36	93.16^{a-c} ±1.91	127.70^{b} ±11.44	87.49^{b-d} ±7.06	120.71^{bc} ±5.34	112.74^{b-d} ±4.97	110.53^{c-g} ±7.89	78.95^{c-g} ±7.89	121.03^{c-e} ±7.41	89.85^{bc} ±2.69	110.09^{a-e} ±7.06	123.18^{b-g} ±14.34	110.09^{a-e} ±7.06	123.18^{b-g} ±14.34	89.87^{g-k} ±0.71	96.73^{d-h} ±2.29	87.93^{l-n} ±2.59	68.10^{j} ±3.28	88.25^{m-o} ±1.38	92.17^{h-j} ±1.60	100.08^{b-e} ±2.03	97.01^{a} ±2.98
Rihane 03	73.22^{h-k} ±5.24	36.99^{l-n} ±4.58	72.29^{f-i} ±5.02	38.20^{ij} ±3.09	87.86^{f-i} ±2.91	69.38^{j-m} ±6.22	78.13^{h-j} ±6.25	53.13^{g-i} ±3.13	83.11^{i-k} ±4.67	42.10^{l} ±2.46	104.91^{a-f} ±12.62	75.30^{h-l} ±5.66	104.91^{a-f} ±12.62	75.30^{h-l} ±5.66	85.97^{j-l} ±1.74	92.62^{f-j} ±0.98	88.17^{k-n} ±2.89	93.90^{c-g} ±6.11	90.88^{k-n} ±1.29	90.12^{h-j} ±0.89	81.51^{k-m} ±2.15	85.17^{b-e} ±3.19
Tichedrette	121.09^{bc} ±5.74	99.00^{ab} ±4.87	126.64^{b} ±10.29	112.21^{a} ±7.50	114.30^{b-e} ±5.53	121.35^{bc} ±6.36	112.00^{b-g} ±11.14	92.00^{b-e} ±6.32	121.86^{b-e} ±3.80	107.92^{a} ±5.12	117.60^{a-c} ±13.92	119.48^{b-h} ±9.25	117.60^{a-c} ±13.92	119.48^{b-h} ±9.25	86.61^{i-k} ±1.16	91.45^{g-k} ±1.20	81.81^{no} ±2.82	88.56^{e-h} ±1.71	86.15^{op} ±0.89	95.54^{gh} ±1.45	81.15^{lm} ±1.39	82.46^{c-f} ±0.81
Nailia	64.08^{i-l} ±7.33	42.74^{k-m} ±6.63	62.23^{h-j} ±5.31	38.87^{ij} ±6.49	93.01^{e-i} ±5.39	91.05^{e-j} ±4.78	69.05^{ij} ±3.15	40.48^{i} ±6.63	73.48^{k-m} ±3.87	58.43^{i-k} ±3.19	105.65^{a-f} ±7.63	184.64^{a} ±35.02	105.65^{a-f} ±7.63	184.64^{a} ±35.02	88.30^{g-k} ±0.49	101.65^{cd} ±2.70	87.20^{l-n} ±3.04	81.34^{hi} ±2.30	89.21^{l-o} ±1.11	95.91^{gh} ±0.36	92.76^{f-h} ±3.42	95.28^{a} ±1.28
Temacine	86.66^{f-i} ±1.20	45.97^{i-m} ±5.27	94.24^{c-g} ±5.33	47.42^{g-j} ±4.37	73.71^{ij} ±7.91	59.51^{lm} ±5.52	135.29^{a-d} ±15.56	79.41^{c-g} ±7.64	97.62^{g-i} ±3.32	65.66^{h-j} ±2.72	75.61^{d-h} ±8.64	83.89^{e-k} ±8.96	75.61^{d-h} ±8.64	83.89^{e-k} ±8.96	85.35^{kl} ±1.50	94.26^{f-j} ±1.33	98.84^{f-j} ±1.40	82.02^{g-i} ±3.40	95.75^{f-j} ±1.23	98.61^{fg} ±1.38	90.16^{g-i} ±1.83	74.79^{f-i} ±0.92
Early 1	111.03^{c-e} ±7.10	102.99^{ab} ±11.60	110.10^{b-d} ±17.29	107.26^{ab} ±14.89	145.15^{a} ±7.91	193.27^{a} ±18.35	75.00^{h-j} ±11.98	60.71^{f-i} ±11.29	81.18^{i-l} ±5.39	84.81^{b-f} ±7.15	120.54^{ab} ±21.38	156.67^{ab} ±23.04	120.54^{ab} ±21.38	156.67^{ab} ±23.04	81.44^{l} ±2.19	111.69^{a} ±2.09	129.17^{a} ±2.78	116.67^{b} ±5.22	81.11^{q} ±1.55	114.17^{a} ±2.45	96.54^{c-g} ±2.32	98.09^{a} ±2.88
Early 2	58.94^{j-l} ±3.67	52.41^{f-l} ±4.60	54.43^{ij} ±6.41	53.26^{f-j} ±5.38	103.41^{c-g} ±14.09	102.14^{c-e} ±4.98	60.98^{j} ±11.44	51.22^{hi} ±3.66	56.73^{n} ±2.43	58.33^{i-k} ±5.34	115.60^{a-d} ±26.05	108.96^{c-i} ±13.73	115.60^{a-d} ±26.05	108.96^{c-i} ±13.73	95.43^{c-f} ±1.98	89.18^{i-l} ±5.63	125.93^{ab} ±4.48	144.52^{a} ±10.86	98.41^{d-g} ±2.04	110.08^{ab} ±5.31	106.66^{b} ±2.37	92.59^{ab} ±4.30
Giza 123	76.58^{g-j} ±3.96	55.62^{f-l} ±4.08	80.39^{e-i} ±4.49	66.93^{d-h} ±7.65	86.91^{f-i} ±6.55	99.42^{d-f} ±7.24	96.97^{f-i} ±10.28	66.67^{e-i} ±6.60	77.60^{j-l} ±2.19	59.17^{i-k} ±3.04	83.32^{b-h} ±10.69	88.97^{d-k} ±8.70	83.32^{b-h} ±10.69	88.97^{d-k} ±8.70	91.91^{e-h} ±1.12	97.53^{d-g} ±1.24	102.76^{f-h} ±1.44	117.37^{b} ±2.83	94.45^{g-k} ±1.72	102.19^{d-f} ±1.18	99.04^{c-f} ±1.91	94.70^{a} ±1.68
Giza 125	166.42^{a} ±15.02	92.63^{a-c} ±7.86	172.97^{a} ±16.19	98.91^{a-c} ±8.16	124.57^{b} ±6.47	128.65^{b} ±5.97	141.67^{a-c} ±13.66	79.17^{c-g} ±7.51	178.26^{a} ±6.45	97.05^{ab} ±3.25	131.10^{a} ±14.87	129.06^{b-e} ±16.94	131.10^{a} ±14.87	129.06^{b-e} ±16.94	91.65^{e-i} ±1.18	109.05^{ab} ±0.75	130.83^{a} ±2.79	120.94^{b} ±2.53	99.33^{d-f} ±1.23	106.94^{b-d} ±1.33	94.90^{d-h} ±1.73	92.25^{ab} ±1.60
Giza 126	120.78^{bc} ±4.68	68.92^{d-h} ±4.97	99.09^{c-g} ±5.27	62.67^{e-h} ±4.44	89.37^{f-i} ±4.73	74.47^{h-l} ±6.17	104.00^{d-h} ±4.00	84.00^{c-f} ±6.00	122.30^{b-e} ±5.03	81.09^{b-h} ±4.22	114.60^{a-d} ±10.92	93.56^{d-k} ±5.25	114.60^{a-d} ±10.92	93.56^{d-k} ±5.25	96.43^{c-e} ±1.89	96.34^{d-h} ±3.06	90.40^{j-n} ±1.95	82.97^{g-i} ±0.77	100.91^{de} ±1.47	91.10^{h-j} ±1.54	102.76^{bc} ±1.21	80.29^{d-g} ±2.12
Giza 127	96.49^{e-g}	65.24^{e-i}	81.61^{e-h}	60.82^{e-i}	78.38^{ij}	70.70^{i-m}	104.00^{d-h}	88.00^{b-f}	108.61^{d-g}	83.58^{b-g}	101.13^{a-f}	92.65^{d-k}	101.13^{a-f}	92.65^{d-k}	92.64^{d-g}	98.90^{c-f}	101.97^{f-i}	101.71^{cd}	98.04^{e-h}	100.39^{e-g}	82.66^{j-m}	78.44^{d-i}

	±6.08	±6.77	±5.99	±4.67	±4.17	±5.55	±4.00	±6.32	±3.48	±4.76	±6.08	±6.02	±6.08	±6.02	±1.46	±2.01	±5.11	±2.97	±1.64	±0.70	±1.46	±2.03
Giza 129	94.37 $^{e-h}$	77.28 $^{c-e}$	97.33 $^{c-g}$	65.40 $^{d-h}$	82.88 $^{g-i}$	88.27 $^{e-k}$	119.23 $^{b-f}$	73.08 $^{d-h}$	108.59 $^{d-g}$	87.15 $^{b-d}$	91.52 $^{a-g}$	150.94 $^{a-c}$	91.52 $^{a-g}$	150.94 $^{a-c}$	92.66 $^{d-g}$	101.14 $^{c-e}$	95.09 $^{g-m}$	93.03 $^{d-h}$	93.53 $^{h-l}$	96.05 ^{gh}	89.88 $^{g-i}$	90.07 $^{a-c}$
	±5.68	±7.87	±6.32	±8.19	±7.42	±4.21	±8.38	±12.16	±5.11	±9.13	±4.96	±34.88	±4.96	±34.88	±1.59	±2.19	±2.88	±1.90	±1.90	±2.02	±1.97	±0.88
Giza 130	162.33 ^{a}	76.27 $^{c-e}$	166.56 ^{a}	74.46 $^{d-f}$	91.48 $^{f-i}$	92.16 $^{e-i}$	159.09 ^{a}	72.73 $^{d-h}$	137.81 ^{b}	86.31 $^{b-e}$	72.57 $^{e-h}$	107.99 $^{c-j}$	72.57 $^{e-h}$	107.99 $^{c-j}$	106.08 ^{ab}	101.84 ^{cd}	98.56 $^{f-k}$	86.85 $^{e-h}$	106.77 ^{b}	105.52 $^{b-e}$	116.36 ^{a}	92.66 ^{ab}
	±7.11	±7.91	±8.16	±8.67	±4.37	±4.15	±10.66	±9.09	±8.78	±6.68	±8.52	±17.50	±8.52	±17.50	±1.40	±2.21	±3.52	1.99	±1.23	±1.25	±3.91	±5.58
Giza 131	75.74 $^{g-j}$	60.12 $^{e-k}$	93.33 $^{c-g}$	64.28 $^{d-h}$	100.82 $^{c-h}$	78.34 $^{f-l}$	92.31 $^{f-i}$	84.62 $^{c-f}$	87.59 $^{h-k}$	68.11 $^{f-i}$	97.52 $^{a-g}$	81.58 $^{f-k}$	97.52 $^{a-g}$	81.58 $^{f-k}$	97.87 ^{cd}	85.83 ^{kl}	99.69 $^{f-j}$	85.96 $^{e-h}$	99.63 $^{d-f}$	92.01 $^{h-j}$	88.08 $^{h-k}$	82.47 $^{c-f}$
	±6.67	±4.10	±5.93	±2.99	±3.77	±6.03	±5.77	±6.08	±7.69	±5.01	±11.07	±7.85	±11.07	±7.85	±1.93	±1.09	±2.88	±1.50	±0.47	±0.81	±2.78	±0.93
Giza 2000	52.79 ^{kl}	31.59 ^{mn}	44.71 ^{j}	31.66 ^{i}	83.88 $^{f-i}$	78.05 $^{f-l}$	56.76 ^{j}	40.54 ^{i}	59.56 ^{mn}	45.25 ^{kl}	118.17 $^{a-c}$	127.58 $^{b-f}$	118.17 $^{a-c}$	127.58 $^{b-f}$	103.07 ^{b}	105.01 ^{bc}	105.75 $^{e-f}$	104.83 ^{c}	113.28 ^{a}	108.91 ^{bc}	100.97 $^{b-d}$	97.83 ^{a}
	±4.29	±3.62	±4.65	±4.01	±6.55	±5.03	±7.02	±5.73	±4.50	±3.01	±16.98	±16.28	±16.98	±16.28	±1.94	±0.85	±2.99	±1.79	±1.27	±2.06	±1.02	±2.09
El Arich	105.62 $^{c-f}$	21.34 ^{n}	93.08 $^{c-g}$	44.09 $^{h-j}$	94.88 $^{d-i}$	71.22 $^{h-m}$	94.44 $^{f-i}$	61.11 $^{f-i}$	103.34 $^{f-h}$	23.70 ^{m}	100.24 $^{a-f}$	35.54 ^{l}	100.24 $^{a-f}$	35.54 ^{l}	109.70 ^{a}	109.66 ^{ab}	113.90 $^{d-e}$	91.56 $^{d-h}$	105.89 ^{bc}	103.95 $^{c-f}$	82.24 $^{j-m}$	82.19 $^{c-f}$
	±4.94	±1.41	±6.70	±8.57	±5.38	±11.24	±8.10	±4.39	±5.60	±0.73	±7.42	±2.92	±7.42	±2.92	±2.02	±1.11	±2.60	±5.71	±1.13	±2.51	±3.14	±2.97
Total Mean	94.00	63.11	95.20	66.96	93.48	87.11	104.24	78.93	97.83	71.97	96.83	97.38	96.83	97.38	93.23	96.01	99.44	93.55	95.10	96.28	90.50	83.09
Std. Error of Total Mean	±2.05	±1.58	±2.15	±1.69	±1.53	±1.90	±2.18	±1.82	±1.76	±1.40	±2.30	±3.01	±2.30	±3.01	±0.49	±0.56	±0.98	±1.07	±0.49	±0.55	±0.67	±0.80

Table 1. Continued from previous page.

	c. Calculated ratio																	
Genotypes	Sh/R (g/g)		LN/TN (n/n)		SN/TN (n/n)		S/Sh (g/g)		R/Sh (g/g)		GY/Sh (g/g)		GY/ W (g/g)		GY/Sh+R (g/g)		HI (g/g)	
Kebelli 2	144.75 ^{fg}	118.36 $^{h-j}$	103.53 $^{d-g}$	88.51 $^{g-j}$	135.84 ^{a}	137.98 ^{ab}	94.89 $^{h-l}$	112.71 $^{a-d}$	69.07 $^{j-m}$	85.76 $^{e-g}$	91.46 $^{g-j}$	77.20 $^{j-l}$	96.39 $^{i-l}$	86.24 $^{f-h}$	92.87 ^{ij}	81.89 $^{g-i}$	101.27 $^{d-g}$	90.83 $^{d-j}$
	±6.27	±7.19	±2.31	±2.58	±7.92	±11.34	±3.29	±4.28	±2.68	±5.06	±1.73	±4.86	±2.45	±3.34	±3.54	±4.71	±4.36	±2.61
Tozeur 2	65.05 ^{m}	71.05 ^{mn}	127.70 ^{ab}	105.62 $^{b-g}$	113.61 ^{bc}	86.26 ^{fg}	164.76 ^{a}	128.95 ^{a}	151.92 ^{a}	129.63 ^{c}	128.88 $^{b-d}$	122.87 $^{b-d}$	103.02 $^{g-k}$	103.93 $^{c-e}$	123.67 $^{c-e}$	122.23 ^{bc}	104.93 $^{c-f}$	98.43 $^{b-h}$
	±3.55	±2.55	±3.18	±5.95	±14.55	±7.92	±24.84	±6.02	±7.00	±10.43	±5.83	±4.10	±5.20	±3.64	±8.96	±3.17	±5.29	±3.93
Rihane	131.36 ^{gh}	82.65 $^{k-m}$	102.79 $^{d-g}$	142.41 ^{a}	124.10 ^{ab}	130.12 ^{bc}	106.59 $^{e-j}$	77.80 $^{h-j}$	74.00 $^{h-k}$	130.37 ^{c}	134.55 $^{a-c}$	82.30 $^{h-k}$	117.47 $^{b-f}$	85.13 $^{f-h}$	126.33 ^{cd}	74.34 ^{hi}	116.10 $^{a-c}$	85.93 $^{h-k}$
	±6.56	±5.51	±3.10	±6.97	±4.09	±0.00	±3.55	±5.71	±4.38	±8.97	±2.54	±2.65	±2.67	±2.88	±2.79	±2.69	±2.68	±2.84
Manel	205.28 ^{ab}	167.52 ^{bc}	114.53 $^{b-d}$	109.82 $^{b-f}$	100.00 $^{c-e}$	117.14 ^{cd}	121.59 $^{b-f}$	115.86 $^{a-c}$	49.42 ^{o}	60.54 $^{j-l}$	102.63 $^{f-h}$	94.70 $^{f-h}$	98.48 $^{h-l}$	91.32 $^{e-h}$	116.25 $^{d-g}$	115.27 ^{cd}	90.23 $^{g-i}$	88.53 $^{e-k}$
	±10.82	±8.20	±3.84	±4.31	±5.90	±0.00	±4.30	±5.70	±2.71	±3.53	±7.15	±5.24	±4.69	±7.14	±7.48	±5.85	±6.02	±6.85
Jerba	153.20 ^{ef}	97.91 $^{j-l}$	112.31 $^{b-d}$	111.79 $^{b-d}$	103.47 ^{cd}	98.43 $^{d-g}$	88.75 $^{i-l}$	87.17 $^{e-j}$	64.03 $^{k-n}$	101.09 ^{d}	99.73 $^{g-i}$	111.39 $^{c-e}$	105.14 $^{f-j}$	98.63 $^{c-f}$	108.55 $^{e-i}$	109.44 ^{cd}	101.70 $^{d-g}$	103.37 $^{b-d}$
	±3.47	±3.94	±5.06	±6.07	±5.71	±6.45	±3.86	±6.47	±1.33	±4.04	±3.61	±3.34	±4.49	±1.90	±4.23	±2.54	±2.39	±2.61
Sidi Bouzid	102.23 $^{i-k}$	143.70 $^{d-g}$	112.97 $^{b-d}$	113.90 ^{bc}	106.96 $^{b-d}$	103.48 $^{d-g}$	119.07 $^{b-g}$	103.57 $^{b-g}$	101.54 ^{de}	72.35 $^{g-k}$	122.04 $^{c-e}$	98.11 $^{e-g}$	126.14 ^{bc}	120.53 ^{b}	121.17 $^{c-f}$	112.46 ^{cd}	111.64 $^{b-d}$	103.92 $^{b-d}$
	±7.73	±10.42	±7.57	±5.63	±7.41	±7.81	±6.48	±8.93	±7.19	±5.62	±7.95	±7.49	±6.32	±7.39	±8.21	±11.04	±5.26	±6.28
Kairouan	74.81 ^{lm}	125.57 ^{gh}	92.74 $^{e-i}$	99.31 $^{c-h}$	101.89 ^{cd}	110.07 ^{de}	133.38 $^{b-d}$	100.74 $^{b-h}$	130.75 ^{b}	77.47 $^{g-i}$	129.71 $^{a-d}$	79.68 $^{i-l}$	97.15 $^{i-l}$	80.77 $^{g-i}$	118.21 $^{d-g}$	86.81 ^{gh}	106.29 $^{c-f}$	88.95 $^{e-k}$
	±2.89	±3.24	±4.99	±6.25	±6.01	±4.68	±6.90	±5.07	±4.63	±2.02	±3.90	±4.12	±3.28	±3.84	±4.61	±5.37	±2.97	±4.55
Gabès	187.83 ^{bc}	149.39 $^{c-f}$	85.79 $^{g-j}$	93.83 $^{e-i}$	111.00 ^{bc}	107.09 ^{de}	101.38 $^{f-l}$	101.05 $^{b-h}$	53.03 ^{no}	69.57 $^{h-k}$	104.83 ^{fg}	65.96 ^{l}	103.23 $^{g-k}$	70.87 ^{i}	118.65 $^{c-g}$	85.07 ^{gh}	98.61 $^{d-h}$	72.36 ^{lm}
	±4.67	±11.63	±4.90	±5.46	±7.09	±6.55	±4.06	±3.18	±1.31	±5.25	±3.30	±4.42	±2.84	±5.14	±4.32	±6.54	±2.44	±5.71
Tozeur 1	124.22 $^{g-i}$	154.43 $^{b-e}$	87.56 $^{f-j}$	87.38 $^{h-j}$	98.88 $^{c-f}$	95.71 $^{e-g}$	96.18 $^{h-l}$	75.47 ^{ij}	80.93 $^{g-j}$	61.43 $^{j-l}$	100.13 $^{g-i}$	78.69 $^{j-l}$	99.66 $^{g-l}$	87.54 $^{f-h}$	107.24 $^{f-i}$	88.60 ^{gh}	97.53 $^{e-h}$	87.48 $^{f-k}$
	±3.76	±7.29	±6.69	±4.86	±5.45	±6.17	±7.22	±9.39	±2.40	±4.33	±4.67	±2.10	±3.48	±2.53	±4.96	±4.11	±3.52	±3.25
Tombari	127.65 ^{gh}	105.32 ^{ij}	86.12 $^{g-j}$	63.56 ^{kl}	73.55 ^{g}	99.05 $^{d-g}$	60.61 ^{m}	80.58 $^{g-j}$	79.03 $^{g-j}$	95.24 $^{d-f}$	68.78 ^{l}	66.17 ^{l}	86.87 ^{l}	87.49 $^{f-h}$	71.94 ^{k}	68.07 ^{i}	88.81 $^{g-i}$	76.34 ^{kl}
	±6.55	±4.73	±3.50	±6.88	±4.81	±3.81	±1.19	±4.77	±4.41	±4.59	±2.04	±5.93	±2.44	±6.69	±2.86	±6.12	±2.66	±6.85
Kerkena	211.11 ^{a}	136.37 $^{e-h}$	81.26 ^{ij}	83.98 $^{h-j}$	80.38 $^{e-g}$	107.10 ^{de}	79.48 ^{lm}	122.24 ^{ab}	48.28 ^{o}	72.87 $^{g-j}$	72.59 ^{kl}	125.33 ^{b}	89.77 ^{kl}	110.54 ^{bc}	82.39 ^{jk}	132.85 ^{b}	83.95 ^{i}	107.15 ^{b}
	±12.53	±2.52	±3.96	±6.16	±4.52	±2.43	±2.71	±3.70	±2.84	±1.26	±3.36	±2.81	±2.93	±2.08	±4.23	±4.23	±3.55	±1.94
Sidi Mahdi	94.42 $^{j-l}$	101.98 $^{i-l}$	78.58 ^{ij}	65.37 ^{kl}	106.34 $^{b-d}$	150.00 ^{a}	79.81 ^{lm}	95.84 $^{c-i}$	92.46 $^{e-g}$	84.06 $^{f-h}$	41.00 ^{m}	46.32 ^{m}	44.61 ^{m}	46.91 ^{j}	48.95 ^{l}	53.10 ^{j}	45.46 ^{j}	49.63 ^{n}
	±6.10	±4.77	±5.69	±3.42	±9.55	±8.30	±5.91	±5.31	±5.88	±3.26	±2.64	±2.81	±3.54	±3.55	±2.59	±3.64	±3.48	±2.81
Ras El Mouche	123.66 $^{g-i}$	102.64 $^{i-k}$	83.38 $^{h-j}$	73.93 $^{j-l}$	96.21 $^{c-f}$	94.70 $^{e-g}$	91.00 $^{i-l}$	91.68 $^{d-j}$	82.95 $^{f-j}$	98.22 ^{de}	89.07 $^{h-j}$	100.53 $^{e-g}$	90.73 $^{j-l}$	93.59 $^{d-g}$	92.73 ^{ij}	93.71 ^{fg}	90.82 $^{g-i}$	86.85 $^{g-k}$
	±9.77	±5.75	±10.15	±6.98	±4.17	±5.01	±6.60	±2.82	±5.65	±5.69	±3.62	±5.80	±4.83	±5.73	±3.97	±5.15	±1.49	±4.22
Ksar Megarine	114.99 $^{h-j}$	119.98 ^{hi}	91.68 $^{e-i}$	92.24 $^{f-i}$	106.15 $^{b-d}$	106.15 $^{d-f}$	103.00 $^{f-k}$	84.55 $^{f-j}$	85.88 $^{f-i}$	82.59 $^{f-h}$	98.23 $^{g-i}$	80.04 $^{i-l}$	99.26 $^{g-l}$	77.66 ^{hi}	107.58 $^{f-i}$	85.89 ^{gh}	87.24 ^{hi}	80.71 $^{j-l}$
	±2.25	±3.41	±5.75	±7.15	±7.02	±4.99	±5.38	±4.96	±1.53	±2.27	±5.92	±2.57	±3.79	±3.69	±6.83	±2.44	±7.44	±3.49
Saida	89.90 ^{kl}	133.01 $^{f-h}$	100.84 $^{d-h}$	92.82 $^{f-i}$	86.19 $^{d-g}$	105.15 $^{d-g}$	134.41 ^{bc}	122.21 ^{ab}	109.36 ^{cd}	73.92 $^{g-j}$	139.14 ^{ab}	138.61 ^{a}	130.68 ^{ab}	145.26 ^{a}	143.32 ^{b}	160.08 ^{a}	127.20 ^{a}	129.42 ^{a}
	±4.54	±5.99	±4.75	±8.47	±5.08	±9.78	±11.24	±8.96	±5.53	±4.22	±5.74	±6.73	±4.26	±9.29	±6.18	±9.39	±4.36	±3.13
Azrir	124.39 $^{g-i}$	173.22 ^{ab}	104.53 $^{d-f}$	84.85 $^{h-j}$	92.59 $^{d-g}$	90.74 $^{e-g}$	98.76 $^{g-l}$	69.28 ^{j}	82.28 $^{f-j}$	57.52 ^{kl}	90.56 $^{h-j}$	72.94 ^{kl}	104.79 $^{f-j}$	95.53 $^{d-g}$	105.04 $^{g-i}$	88.42 ^{gh}	97.19 $^{e-h}$	87.59 $^{f-k}$
	±8.86	±7.88	±6.40	±2.65	±4.90	±6.28	±3.35	±4.93	±6.11	±2.41	±3.56	±1.57	±4.73	±4.50	±3.82	±2.66	±3.76	±2.61
Rihane 03	169.48 $^{c-e}$	97.61 $^{j-l}$	111.92 $^{b-d}$	100.74 $^{c-h}$	104.09 ^{cd}	86.36 ^{fg}	111.39 $^{d-i}$	68.29 ^{j}	59.74 $^{l-o}$	101.80 ^{d}	114.19 ^{ef}	71.18 ^{kl}	109.35 $^{e-i}$	87.26 $^{f-h}$	126.81 ^{cd}	72.10 ^{hi}	103.92 $^{c-f}$	83.54 $^{i-l}$
	±11.93	±4.45	±5.31	±7.73	±6.13	±7.45	±4.12	±5.22	±3.81	±4.54	±4.16	±6.11	±5.06	±4.68	±4.22	±6.95	±4.86	±5.41
Tichedrette	201.25 ^{ab}	190.38 ^{a}	93.32 $^{e-i}$	85.86 $^{h-j}$	95.75 $^{c-f}$	102.25 $^{d-g}$	126.20 $^{b-e}$	121.82 ^{ab}	49.80 ^{no}	53.35 ^{l}	119.64 ^{de}	110.65 ^{de}	118.56 $^{b-f}$	110.63 ^{bc}	128.22 ^{cd}	121.70 ^{bc}	101.83 $^{d-g}$	96.91 $^{b-h}$
	±6.67	±9.56	±3.51	±3.43	±8.91	±9.79	±3.48	±5.36	±1.55	±2.89	±3.74	±5.97	±2.06	±3.73	±3.79	±2.69	±1.83	±3.58
Nailia	171.45 $^{c-e}$	81.73 ^{lm}	108.62 $^{c-e}$	144.91 ^{a}	89.59 $^{d-g}$	107.51 ^{de}	87.01 $^{j-l}$	79.54 $^{h-j}$	58.49 $^{m-o}$	120.48 ^{c}	87.35 ^{ij}	88.39 $^{f-j}$	112.55 $^{c-h}$	86.58 $^{f-h}$	97.01 $^{h-j}$	82.67 $^{g-i}$	98.62 $^{d-h}$	85.77 $^{h-k}$

	±8.71	±1.64	±9.09	±4.28	±6.14	±0.00	±8.97	±5.69	±3.10	±2.44	±2.46	±3.68	±6.58	±5.87	±1.97	±5.52	±3.09	±2.83
Temacine	76.44 ^{lm}	60.67 ^{no}	81.72 ^{ij}	87.65 $^{g-j}$	102.99 ^{cd}	91.08 $^{e-g}$	86.13 $^{j-l}$	89.88 $^{d-j}$	129.03 ^{b}	162.65 ^{b}	86.80 ^{ij}	93.36 $^{f-i}$	85.85 ^{l}	85.99 $^{f-h}$	81.80 ^{jk}	81.55 $^{g-i}$	87.68 ^{hi}	88.09 $^{f-k}$
	±1.75	±1.44	±5.41	±5.71	±6.66	±7.00	±4.72	±6.66	±2.96	±4.09	±1.59	±3.27	±2.68	±2.64	±2.29	±3.49	±2.94	±2.06
Early 1	145.19 ^{fg}	173.34 ^{ab}	125.44 $^{a-c}$	111.03 $^{b-e}$	100.00 $^{c-e}$	100.00 $^{d-g}$	104.93 $^{e-k}$	91.81 $^{d-j}$	70.68 $^{j-m}$	57.50 ^{kl}	130.04 $^{a-d}$	101.05 $^{e-g}$	124.86 $^{b-d}$	102.79 $^{c-e}$	146.03 ^{b}	110.17 ^{cd}	105.93 $^{c-f}$	104.80 ^{bc}
	±11.63	±8.83	±4.56	±5.65	±0.00	±0.00	±3.92	±8.00	±5.52	±2.68	±5.60	±4.40	±6.94	±2.78	±5.94	±5.54	±5.54	±2.85
Early 2	169.77 $^{c-e}$	158.58 $^{b-d}$	103.17 $^{d-g}$	85.88 $^{h-j}$	98.37 $^{c-f}$	85.20 ^{g}	92.33 $^{h-l}$	84.95 $^{f-j}$	72.96 $^{i-l}$	76.90 $^{g-i}$	92.89 $^{g-j}$	90.24 $^{f-j}$	94.19 $^{j-l}$	95.66 $^{d-g}$	96.78 $^{h-j}$	82.54 $^{g-i}$	97.32 $^{e-h}$	101.46 $^{b-e}$
	±11.72	±10.03	±10.83	±5.87	±4.26	±6.12	±3.75	±7.14	±5.87	±4.40	±4.36	±2.87	±2.61	±3.97	±3.73	±3.46	±2.29	±3.69
Giza 123	104.16 $^{i-k}$	145.73 $^{d-g}$	132.34 ^{a}	121.59 ^{b}	100.95 $^{c-e}$	100.00 $^{d-g}$	103.24 $^{f-k}$	107.93 $^{a-f}$	95.76 ^{ef}	70.39 $^{h-k}$	105.34 ^{fg}	79.92 $^{i-l}$	95.35 $^{i-l}$	94.85 $^{d-g}$	93.52 ^{ij}	80.84 $^{g-i}$	97.65 $^{e-h}$	95.75 $^{b-i}$
	±5.44	±12.03	±7.32	±7.08	±1.90	±2.86	±4.21	±5.20	±5.22	±5.44	±2.93	±4.34	±2.82	±3.56	±2.70	±4.86	±3.22	±3.45
Giza 125	205.06 ^{ab}	143.46 $^{d-g}$	105.31 $^{d-f}$	113.76 ^{bc}	133.66 ^{a}	133.66 $^{a-c}$	138.35 ^{ab}	118.72 $^{a-c}$	48.99 ^{o}	69.75 $^{h-k}$	138.75 ^{ab}	106.49 ^{ef}	120.24 $^{b-e}$	107.26 ^{bd}	148.95 ^{b}	115.08 ^{cd}	109.00 $^{b-e}$	99.64 $^{b-g}$
	±7.22	±4.11	±4.10	±6.36	±0.00	±0.00	±7.95	±3.02	±1.80	±1.97	±2.44	±3.46	±3.45	±3.69	±4.14	±4.47	±2.97	±3.21
Giza 126	112.22 $^{h-j}$	151.41 $^{c-f}$	92.84 $^{e-i}$	59.49	97.03 $^{c-f}$	91.09 $^{e-g}$	115.24 $^{c-h}$	109.75 $^{a-e}$	87.29 $^{f-h}$	66.16 $^{i-l}$	139.26 ^{ab}	122.05 $^{b-d}$	113.48 $^{c-g}$	107.91 ^{bd}	126.32 ^{cd}	117.96 $^{b-d}$	119.52 ^{ab}	100.55 $^{b-f}$
	±1.89	±9.11	±2.03	±4.34	±5.02	±6.26	±4.76	±5.35	±1.47	±3.37	±3.30	±5.15	±2.67	±4.21	±3.82	±3.95	±2.87	±2.76
Giza 127	179.91 ^{cd}	150.57 $^{c-f}$	73.52 ^{j}	92.29	97.22 $^{c-f}$	96.30 $^{e-g}$	88.24 $^{i-l}$	85.88 $^{f-j}$	51.31 ^{no}	65.02 $^{i-l}$	105.16 ^{fg}	94.52 $^{f-h}$	104.42 $^{f-j}$	98.20 $^{c-f}$	112.00 $^{d-h}$	88.27 ^{gh}	105.20 $^{c-f}$	95.10 $^{b-i}$
	±6.56	±3.23	±3.51	±2.64	±2.78	±3.70	±1.65	±2.95	±3.40	±1.32	±5.13	±2.42	±3.36	±2.70	±5.61	±1.85	±3.16	±2.71
Giza 129	168.25 $^{c-e}$	119.50 ^{hi}	79.61 ^{ij}	76.98	95.15 $^{c-f}$	91.92 $^{e-g}$	102.55 $^{f-l}$	100.10 $^{b-h}$	59.67 $^{l-o}$	82.88 $^{f-h}$	90.36 $^{h-j}$	121.30 $^{b-d}$	93.55 $^{j-l}$	107.93 ^{bd}	104.17 $^{g-i}$	111.30 ^{cd}	93.96 $^{f-i}$	101.43 $^{b-e}$
	±7.59	±2.85	±4.54	±3.04	±4.46	±7.18	±5.38	±4.45	±3.02	±2.11	±4.58	±5.44	±5.15	±4.21	±7.56	±4.16	±6.06	±5.98
Giza 130	161.72 $^{d-f}$	137.40 $^{d-g}$	89.60 $^{f-j}$	82.83	97.22 $^{c-f}$	93.52 $^{e-g}$	130.29 $^{b-d}$	127.40 ^{a}	57.42 $^{m-o}$	72.30 $^{g-k}$	127.59 $^{b-d}$	124.47 ^{bc}	141.00 ^{a}	138.39 ^{a}	164.37 ^{a}	160.45 ^{a}	128.02 ^{a}	133.95 ^{a}
	±3.30	±5.13	±1.63	±3.22	±2.78	±4.34	±2.13	±5.32	±2.99	±2.69	±3.26	±4.33	±2.53	±5.18	±3.94	±6.51	±2.32	±2.83
Giza 131	160.13 $^{d-f}$	100.43 $^{i-l}$	111.68 $^{b-d}$	96.04	105.88 $^{b-d}$	105.88 $^{d-f}$	104.59 $^{e-k}$	105.45 $^{a-g}$	59.79 $^{l-o}$	100.03 ^{d}	82.56 ^{jk}	99.78 $^{e-g}$	88.74 ^{kl}	99.88 $^{c-f}$	104.18 $^{g-i}$	104.03 ^{ef}	99.25 $^{d-h}$	99.68 $^{b-g}$
	±5.37	±4.43	±3.05	±3.15	±0.00	±0.00	±5.44	±2.87	±3.62	±3.86	±6.17	±2.94	±7.63	±2.58	±6.46	±3.56	±4.27	±2.44
Giza 2000	84.22 $^{k-m}$	103.32 $^{i-k}$	109.87 $^{c-e}$	95.24	78.70 ^{fg}	96.30 $^{e-g}$	82.55 ^{kl}	72.88 ^{ij}	116.09 ^{c}	94.79 $^{d-f}$	100.90 $^{f-i}$	72.64 ^{kl}	111.62 $^{d-h}$	93.44 $^{d-g}$	102.65 $^{g-i}$	77.55 $^{g-i}$	103.91 $^{c-f}$	92.96 $^{c-j}$
	±3.79	±4.43	±1.44	±4.34	±7.23	±3.70	±4.30	±4.10	±4.96	±4.71	±2.82	±2.68	±7.51	±2.43	±3.38	±3.96	±1.88	±2.56
El Arich	74.76 ^{lm}	46.67 ^{o}	103.41 $^{d-g}$	89.96	100.00 $^{c-e}$	105.42 $^{d-g}$	122.42 $^{b-f}$	123.97 ^{ab}	136.39 ^{b}	213.92 ^{a}	142.88 ^{a}	52.63 ^{m}	119.83 $^{b-e}$	47.43 ^{j}	134.39 ^{bc}	48.17 ^{j}	127.08 ^{a}	62.81 ^{m}
	±4.32	±1.48	±4.55	±2.94	±4.51	±3.01	±1.68	±24.30	±8.56	±6.71	±2.76	±3.20	±2.23	±2.71	±3.16	±4.12	±2.24	±3.11
Total Mean	137.38	124.00	99.63	95.28	101.09	104.05	105.46	98.65	80.91	89.05	105.71	92.56	104.10	95.04	111.36	97.18	100.90	92.90
Std. Error of of Total Mean	±2.83	±2.35	±1.28	±1.48	±1.30	±1.35	±1.72	±1.62	±1.85	±2.14	±1.59	±1.52	±1.28	±1.42	±1.64	±1.78	±1.12	±1.16

Values followed by the same letter are not significantly different using Duncan's multiple range tests ($p \leq 0.05$).

STI: Salt Tolerance Index, Std. Error: standard error, WDW: Whole Dry Weight plant^{-1}, SDW: Spike Dry Weight plant^{-1}, GY: Grain Yield plant^{-1}, ShDW: Shoot Dry Weight plant^{-1}, RDW: Root Dry Weight plant^{-1}, PH: Plant Height, TN: Tiller Number plant^{-1}, LN: Leaf Number plant^{-1}, SN: Spike Number plant^{-1}, GN/P: Grain Number Plant^{-1}, StN: Spikelet Number spike^{-1}, GN/S: Grain Number Spike^{-1}, AL: Awn Length, RL: Rachis Length, SL: Spike Length, TKW: 1000-Kernel Weight (g), Sh/R: Shoot Root dry weight Ratio, LN/TN: Leaf Tiller Number ratio, SN/TN: Spike Tiller Number ratio, S/Sh: Spike Shoot dry weight Ratio, SDW: Spike Dry Weight, R/Sh: Root Shoot dry weight Ratio, GY/Sh: Grain Yield Shoot dry weight Ratio, GY/W: Grain Yield Whole plant dry weight Ratio, GY/Sh+R: Grain Yield Shoot and root dry weight Ratio, HI: Harvest index.

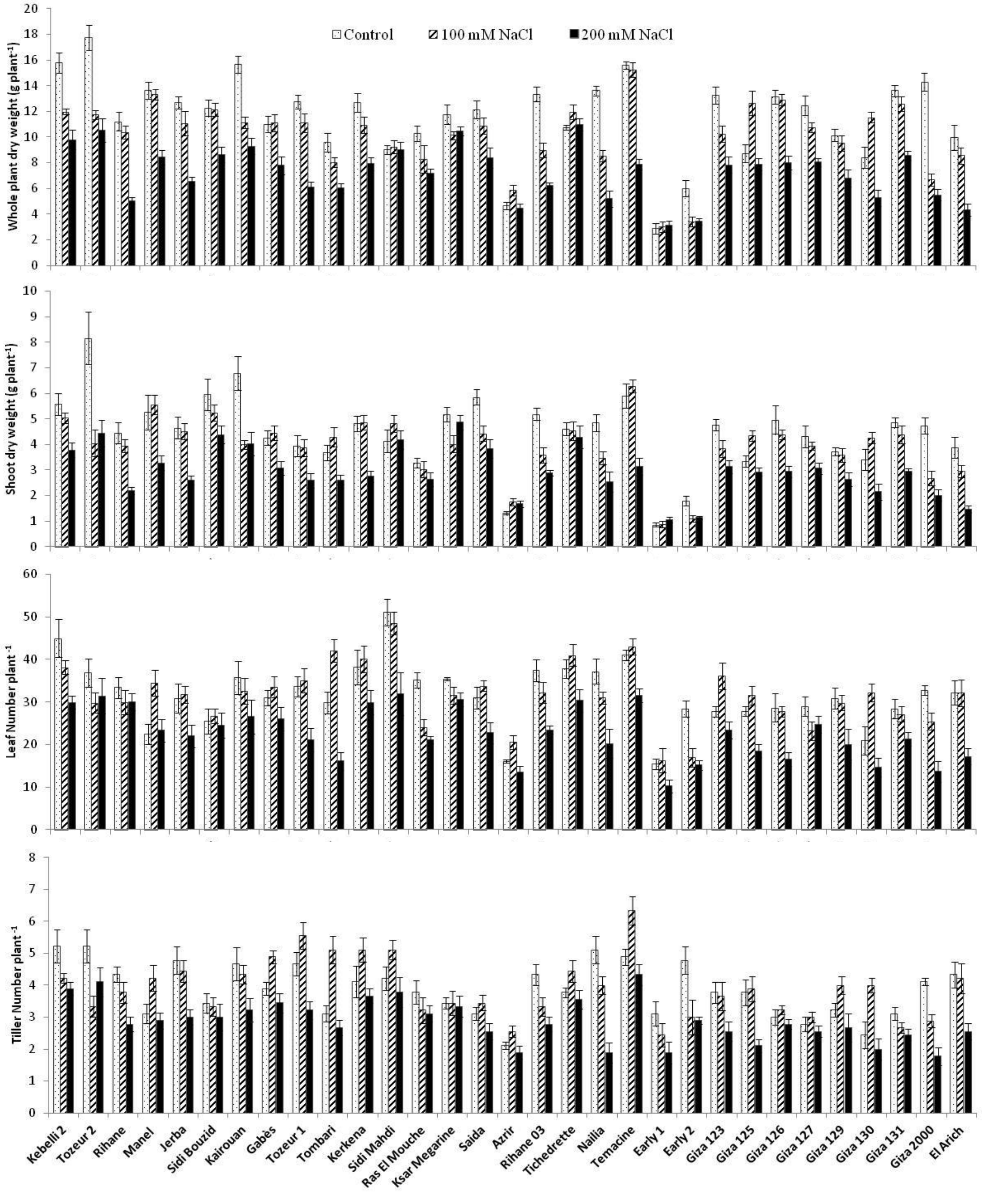

Fig 1. Effect of different salinity levels (0, 100 and 200 mM NaCl) on plant biomass and vegetative traits (whole plant dry weight, shoot dry weight, leaf number per plant and tiller number per plant) for 31 barley genotypes. Error bars represent standard deviations.

respectively. PC2 had high positive coefficients with shoot dry weight at 100 mM NaCl as well as high positive relationship with STI of spike number and tiller number at both salinity levels. The third principal component (PC3) exhibited high positive relationship with STI of root/shoot dry weight ratio at moderate salinity level. In addition, PC3 showed high positive correlation with STI of shoot and root dry weight while, high negative coefficients was observed with STI of all calculated ratio for grain yield at high salinity. In order to obtain distinct groups of barley genotypes according to their STI, PC1 and PC2 were selected at 100 mM NaCl, while PC1 and PC3 were used at 200 mM NaCl.

Barley genotypes were categorized into four groups (A, B, C and D) from the most salt tolerant to the least tolerant genotype based on PCA data carried out at 100 mM (Fig. 4-a) and 200 mM NaCl (Fig. 4-b). For instance, Tichedrett, Azrir and Giza125 included in group A were identified as the most salt tolerant at both salinity levels. However, El Arich and Giza 2000 which belong to group D were salt susceptible genotypes at high salt condition. In summary, our data showed a negative effect of salt stress on almost all morphological traits. At high salinity, discrimination based on grain yield production revealed that Tozeur2, Tichedrett, Kerkena and Kebilli2 exhibited best performance for grain yield (high production), while Saida, Early1, and Tichedrett were identified as high salt tolerant genotypes (high STI for grain yield). The cluster and principal component analysis allowed a clear grouping of 31 barley genotypes according to their STI. Cluster analysis let to distinguish 3 different groups based on STI of grain yield. By PCA, it has been possible to bring out three principal components that have allowed us to discriminate the genotype responses to different level of salinity into 4 groups: highly tolerant, tolerant, moderately tolerant and susceptible.

Discussion

Current programmes focusing on germplasm diversity and crop improvement are a key to sustainable crop production. For the effective exploitation of cereal germplasm, assessment of the available genetic resources seems imperative (Zubair et al., 2007; Singh et al., 2015).

Morphological characterization is an essential step in evaluating the diversity of salt tolerance degree in barley germplasm. Most of the screening studies were limited to characterizing the barley phenotypes at germination and vegetative stage but did not attempt to evaluate the response to salt stress at the reproductive stage. Here, a characterization based on the vegetative, yield and its related traits was investigated, which showed a high intra-specific diversity among the North African genotypes regarding salt tolerance. The existence of a large amount of genetic diversity has been already reported on barley (Royo and Aragues, 1999; Ben Khaled et al., 2012), rice (Mahmood et al., 2009) and wheat (El-Hendawy et al., 2005).

According to our results, barley growth and yield were significantly reduced with increasing salinity. Thereby, the majority of morphological traits were not affected at moderate salinity level. It is well-known that salt stress causes a depressive effect on the growth and development of cereals as demonstrated in previous studies (Zeng and Shannon, 2000; Munns et al., 2006). In the present work, salt stress affected vegetative traits (leaves number and tillers number and shoot and root biomass) resulting in drastic decreases in the yield and its components. However, the plant height was the least affected trait. These results are in a good harmony with those obtained by El Hendawy (2005) and Saqib et al. (2012). A growth decline reflects increased metabolic energy cost and reduced carbon gain, both of which are associated with salt adaptation (Romero-Aranda et al., 2001, Netondo et al., 2004).

The results of the reproductive traits obtained indicated that salinity affected the grain yield through a reduction in various components such as spike number and grain number in most of the genotypes. Similar results were reported in barley, rice and wheat (Khatun et al., 1995; Maas and Grieve, 1990; Zeng and Shannon, 2000; El Hendawy, 2005; Saqib et al., 2012). Since salt stress accelerates maturation and grain filling in some cereal crops (Francois et al., 1986, 1988), the consistent reduction in grain yield observed in the study could be a result of the shortened grain filling period, and a decrease in the spikelet primordial number per spike (Maas and Grieve, 1990; Grieve et al., 1993; Francois et al., 1994; Javed et al., 2003). Among yield component traits, Thousand Kernel Weight (TKW) was less affected by salinity. Similar result has been already found by Royo and Abio (2003). Our data showed a pronounced genetic variability in North African accessions, suggesting that morphological characters were often constitutive and outcome from natural selection. Several works have demonstrated that pre-sowing seed treatments improve germination and growth potential in saline soils (Ashraf and Ruaf, 2001, Anwar et al., 2011). Assuming that genotypes living within unfavorable conditions are subject to selection based on genotype-environment interactions (Ceccarelli et al., 1996; Munns et al., 2002), we suspect that highly tolerant barley genotypes should appear in accessions originating from harsh environments, including salt-affected areas. Multivariate analyses were used to distinguish salt-tolerant genotypes in barley (Jaradat et al., 2004), wheat (El Hendawy et al., 2005; Ahmad et al., 2013; Sardouie-Nasab et al., 2014), and rice (Zeng et al., 2002). Cluster- and PCA-based analyses on STI were used to group salt-tolerant genotypes. Result of the work presented here indicated that a large number of barley genotypes with high tolerances to adverse conditions appeared in various salinity situations. This result confirmed those already obtained for barley (Munns et al., 2002), tomato (Foolad et al., 1998), bean (Bayuelo-Jimennez et al., 2002) and rice (Zeng et al., 2002), which revealed that accessions originating from arid, coastal, or saline areas showed a good tolerance to salt stress.Royo and Aragüés (1999) suggested that the most productive genotypes were not necessarily the least tolerant to salinity. Thus, we have provided evidence for both high performance and salt tolerance in a significant number of genotypes such as Tichedrett (Early1 is an exception to this pattern, as it showed high tolerance but low grain yield production). Moreover, Tichedrett, Azrir and Giza125 identified as salt-tolerant genotypes could serve as potentially novel germplasm. One difficulty in breeding for salinity tolerance is that the low-yielding varieties were less sensitive to salinity than the high-yielding varieties (Shannon, 1997). Among the most productive genotypes at high salinity, Tozeur2, Kerkena and Kebelli2 were not the most salt-tolerant. In fact, Pasternak and De Malach (1994) indicated that yields of crops with high yield potential could be more severely affected by salinity than yields of more salt tolerant crops with lower yield potential.Analyzing to main components for attribute salt tolerance performance by using grain yield traits, vegetative traits and calculated ratios of these traits can discriminate barley genotypes and can be used to identify elite genetic resources in crop improvement and breeding programs. Since the experiment covered mainly genotypes adapted to harsh environmental conditions, the salt

Table 2. Principal component analysis (PCA) of Salt tolerance index (STI) for vegetative traits, yield-related traits and calculated ratio measured on 31 genotypes from North Africa subjected to normal and salt stress condition (0, 100 and 200 mM NaCl).

Treatment	100 mM NaCl			200 mM NaCl		
	PC1	PC2	PC3	PC1	PC2	PC3
Vegetative traits						
Whole Dry Weight plant^{-1}	0.220	0.284	0.015	0.223	0.208	0.303
Shoot Dry Weight plant^{-1}	0.078	0.355	-0.052	0.197	0.157	0.364
Root Dry weight plant^{-1}	-0.058	0.069	0.407	-0.084	0.088	0.320
Plant Height	0.093	0.066	0.062	0.181	-0.051	0.095
Tiller Number plant^{-1}	0.011	0.352	0.148	0.093	0.346	-0.125
Leaf Number plant^{-1}	0.119	0.268	0.141	0.101	0.218	-0.148
Yield-related traits						
Grain Yield plant^{-1}	0.314	0.175	0.012	0.334	0.071	0.036
Spike Dry Weight plant^{-1}	0.271	0.237	0.032	0.250	0.213	0.194
Spike Number plant^{-1}	0.077	0.363	0.138	0.032	0.395	0.001
Grain Number Plant^{-1}	0.293	0.172	0.018	0.302	0.138	-0.018
Spikelet Number spike^{-1}	0.216	-0.242	-0.183	0.209	-0.247	0.079
Grain Number spike^{-1}	0.216	-0.242	-0.183	0.209	-0.247	0.079
Awn Length	0.054	-0.075	0.247	0.037	-0.250	0.198
Rachis Length	0.108	-0.116	0.030	0.079	-0.160	0.141
Spike Length	0.055	-0.135	0.302	0.073	-0.291	0.200
1000-Kernel weight (g)	0.157	-0.084	0.100	0.094	-0.289	0.123
Calculated ratio						
Shoot Root dry weight Ratio	0.074	0.154	-0.474	0.249	0.097	0.063
Leaf Tiller Number ratio	0.116	-0.216	-0.027	-0.004	-0.174	-0.004
Spike Tiller Number ratio	0.111	0.008	-0.006	-0.046	0.185	0.146
Spike Shoot dry weight Ratio	0.256	-0.102	0.166	0.123	0.085	-0.209
Spike Dry Weight	0.238	-0.109	-0.150	0.246	-0.109	0.279
Root Shoot dry weight Ratio	-0.048	-0.190	0.484	-0.245	-0.110	-0.027
Grain Yield Shoot dry weight Ratio	0.298	-0.143	0.121	0.246	-0.091	-0.289
Grain Yield Whole plant dry weight Ratio	0.304	-0.091	-0.025	0.276	-0.109	-0.266
Grain Yield Shoot and root dry weight Ratio	0.331	-0.066	0.003	0.279	-0.026	-0.291
Harvest index	0.272	-0.134	0.102	0.252	-0.159	-0.273
Percentage variation	29.6	24.26	10.18	31.36	21.56	13.09
Percentage cumulative	29.6	53.85	64.05	31.36	52.92	66.01

tolerance established here is of considerable interest in efforts to determine the ultimate tolerance threshold of barley accessions in our collection as well as to identify the highly tolerant genotypes.

Given the highly diversified responses to salt-stress, contrasting genotypes (i.e. Tichedrett "salt-tolerant" and El Arich "salt-sensitive") may be selected for further physiological studies to elucidate specific mechanisms associated with salt-stress tolerance. The salt-stress tolerant genotypes exhibiting high yield potential identified here (i.e. Tichedrett) could be exploited for the development of new breeding lines.

Materials and Methods

Plant materials

Thirty-one barley landraces (accessions and varieties) were collected from temperate, semi-arid and arid areas from North African countries including Tunisia, Algeria and Egypt (Table 3). The geographic distribution of barley landraces studied in the present work was given in Fig 5.

Growing conditions and salinity tolerance assessment

Experiments were carried out under greenhouse condition at the Center of Biotechnology (Borj Cedria, Tunis). The average temperature ranged from 15°C in January to 35°C in July. The seedlings were grown in 5-Kg pots filled with soil and irrigated regularly every three days. Six weeks post germination (4-5 leaf stage); salt treatment was initiated and applied by gradually increasing the salt concentrations rather than sudden salt application, until the final NaCl concentration was reached (100 or 200 mM for moderate and high salinity level respectively) to ovoid osmotic shock. Twenty six quantitative and qualitative traits were evaluated for each plant at harvest occurring 15 weeks after salt treatment (5-month-old seedlings). All barley accessions and varieties were tested under three salt treatments: control (tap water equivalent to 1.156 mS/cm dS m^{-1}), 100 mM and 200 mM salt (NaCl) stress, equivalent respectively to 10.16 mS/cm dS m^{-1}and 19.03 mS/cm dS m^{-1}. Data were recorded on shoot dry weight/plant (g plant^{-1}), root dry weight/plant (g plant^{-1}), spike dry weight/plant (g plant^{-1}), tillers numbers/plant, leaves number/plant, spikes number/plant, spike length (cm), rachis length (cm), awn length (cm), plant height (cm), number of grains/spike and per plant and the 1000-grain weight (g).

Data collection and statistical analysis

The data of measured morphological traits was analysed based on the randomized complete block design (RCBD) model with 9 replicates. Salt tolerance index (STI) of vegetative and reproductive traits was calculated following Ali et al. (2007) as the value of trait under stress condition / value of trait under controlled condition × 100.

All data were statistically analyzed for variance sources and Duncan’s multiple range test at a significant level of 0.05 applied to determine differences among the barley genotypes.

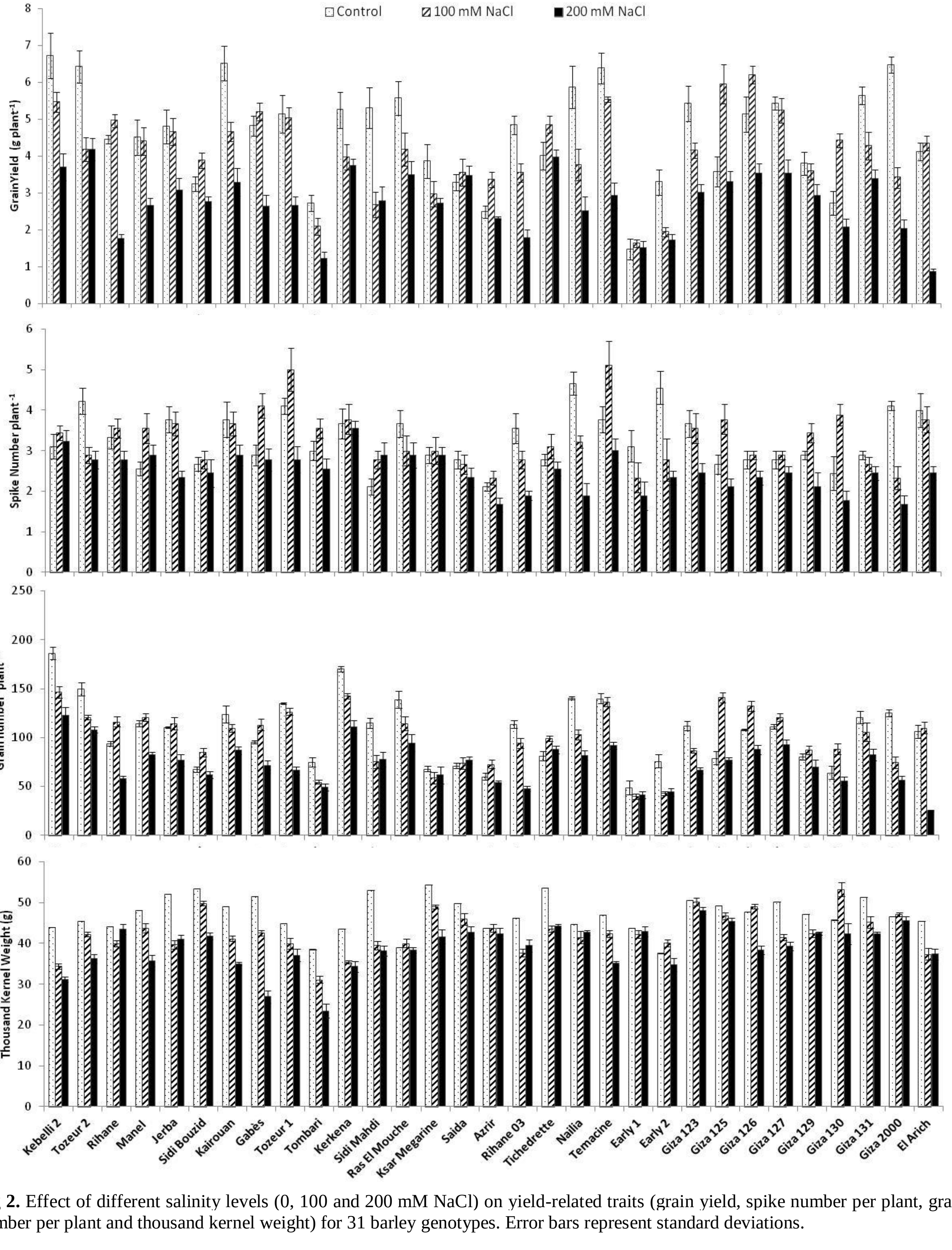

Fig 2. Effect of different salinity levels (0, 100 and 200 mM NaCl) on yield-related traits (grain yield, spike number per plant, grain number per plant and thousand kernel weight) for 31 barley genotypes. Error bars represent standard deviations.

Table 3. Barley accessions and varieties tested.

Serial no.	Acc. /var.	Origin	Description
1	Kebili 2	TUNISIA	Local accession from Kebili region in the south west of Tunisia (Saharian) collected in 2000
2	Tozeur 2	TUNISIA	Local accession from Tozeur oasis in the south west of Tunisia (Saharian) collected in 2000
3	Rihane	TUNISIA	Atlas 46/Arivat//Athenais ICB76-2L-1AP-0AP selected at ICARDA (1976). Improved variety registered in the official catalogue in 1987
4	Manel	TUNISIA	Pure line. Line527/5/As54/Tra//2*Cer/TolI/3/Avt/Toll/ICB81-607-1Kf-1Bj-12Bj-1BJ-1Bj-1Bj-0Bj selected at ICARDA (1996)
5	Jerba	TUNISIA	Local accession from Jerba island in the south east of Tunisia (arid) collected in 1983
6	Sidi Bouzid	TUNISIA	Local accession from Sidi Bouzid region in the central of Tunisia (arid) collected in 2000
7	Kairouan	TUNISIA	Local accession from Kairouan region in the central of Tunisia (arid) collected in 1983
8	Gabès	TUNISIA	Local accession from Gabes region in the central of Tunisia (arid) collected in 2000
9	Tozeur 1	TUNISIA	Local accession from Tozeur oasis in the south west of Tunisia (Saharian) collected in 2000
10	Tombari	TUNISIA	Local accession collected in 2000
11	Kerkena	TUNISIA	Local accession from Kerkena island in the south east of Tunisia (arid) collected in 1983
12	Sidi Mehdi	ALGERIA	Local accession, collected in Adrar/Touat desert.
13	Ras el Mouche	ALGERIA	Local accession from oasis garden (Saharian Population Adrar/Touat).
14	Ksar megarine	ALGERIA	Local accession (Saharian Population Tougourt).
15	Saïda	ALGERIA	Pure line
16	Azrir	ALGERIA	Local accession from oasis garden (Saharian Population Adrar/Touat)
17	Rihane 03	ALGERIA	Pure line. AS 46/AVT 11 ATHS 2L-1AP-3AP-OAP selected at ICARDA (Syria).
18	Tichdrett	ALGERIA	Pure line. C95203S F4N°1998/99.
19	Nailia	ALGERIA	Pure line. CMB 72-189-3Y-IB-2Y-1BX1Y-OB selected at ICSAD (Syria).
20	Temacine	ALGERIA	Local accession (Saharian Population Tougourt).
21	Early1	EGYPT	Local accession
22	Early2	EGYPT	Local accession
23	Giza123	EGYPT	Giza 117/FAO86, year of release 1998.
24	Giza125	EGYPT	Giza 117/Bahteem 52// Giza 118/FAO 86, year of release 1995.
25	Giza126	EGYPT	Bladi Bahteem/SD 729-Por 12762-BC, year of release 1995.
26	Giza127	EGYPT	Year of release 1995.
27	Giza129	EGYPT	Deir Alla 106/Cel//As46/Aths*2, year of release 2000.
28	Giza130	EGYPT	Comp.cross 229//Bco Mr/ DZ02391/3/Deir Alla 106, year of release 2000.
29	Giza131	EGYPT	CM67-B/CENTENO//CAM-B/3/ROW906.73/4/GLORIA-BAR/COME-B/5/FALCON-BAR/6/LINO, year of release 2000.
30	Giza2000	EGYPT	Giza117/Bahteem52//Giza118/FAO 86* Giza 121 Cr.366.13.1/Giza 121, year of release 2000.
31	El Arich	EGYPT	Local accession from Sinai in the north east of Egypt (Semi arid).

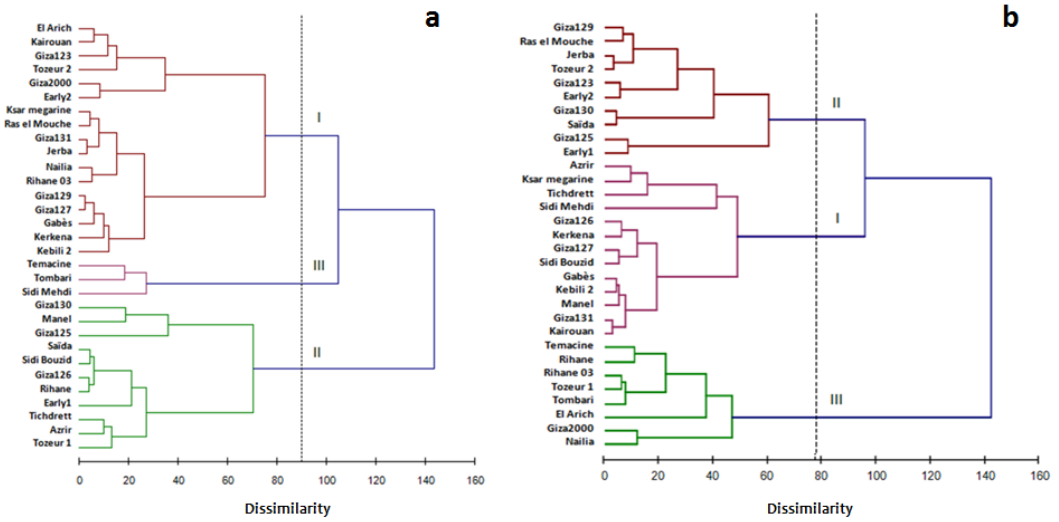

Fig 3. Dendrogram of 31 barley genotypes clustered using the sum of variance squares of Ward's distances subjected to 100 (3-a) and 200 mM NaCl (3-b) respectively. The genotypes were grouped into 3, salt-tolerant, moderately tolerant and salt sensitive clusters with XLSTAT software.

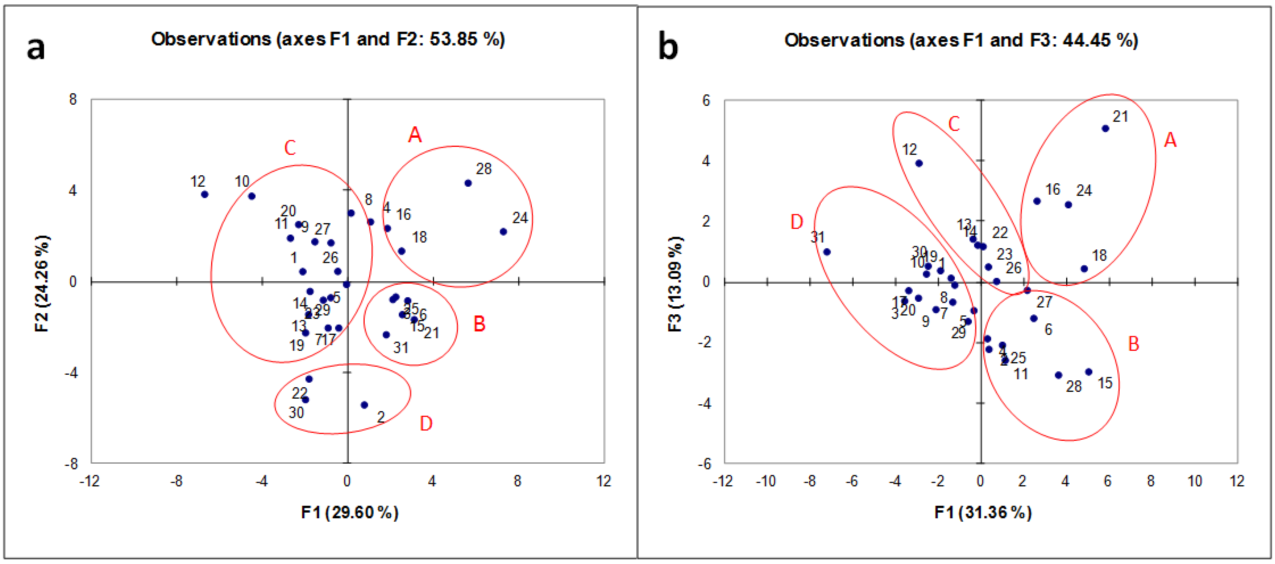

Fig 4. STI-based Principal components analysis (PCA) performed on 26 morphological traits. Barley genotypes are subjected to 100 (4-a) and 200 mM NaCl (4-b) respectively.

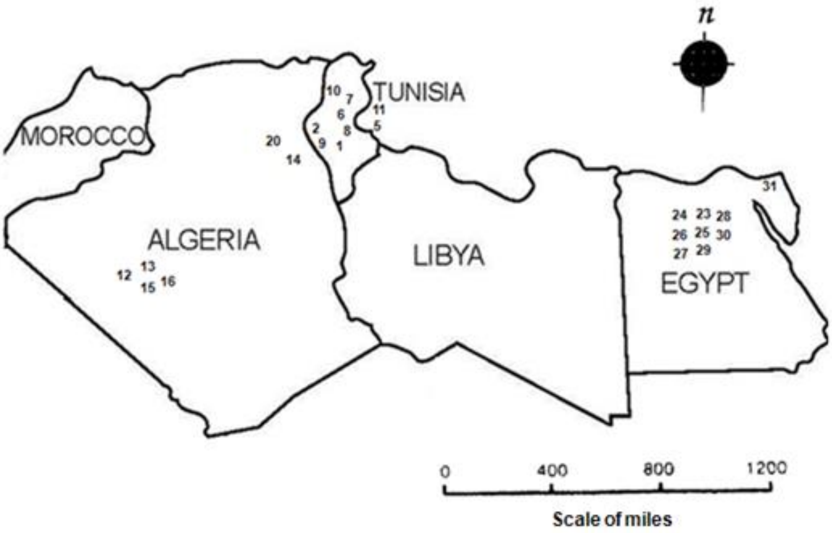

Fig 5. Map of the sampled sites in the North Africa illustrating the geographical distribution of barley landraces used in this study. Landraces were collected from Tunisia (1-11), Algeria (12-20) and Egypt (21-31). Kebili2 (1); Tozeur2 (2); Rihane (3); Manel (4); Jerba (5); Sidi Bouzid (6); Kairouan (7); Gabès (8); Tozeur1(9); Tombari (10); Kerkena (11); Sidi Mehdi (12); Ras el Mouche (13); Ksar megarine (14); Saïda (15); Azrir (16); Rihane03 (17); Tichedrett (18); Nailia (19); Temacine (20); Early1 (21); Early2 (22); Giza123 (23); Giza125 (24); Giza126 (25); Giza127 (26); Giza129 (27); Giza130 (28); Giza131(29); Giza2000 (30); El Arich (31).

Results are significant when p≤ 0.05. Statistical analysis was performed using Statistical Package for Social Sciences (SPSS) software version 16 (2007 Rel 1600 SPSS Inc., Chicago, IL, USA). The means and STI mean values obtained were separated by standard error of the difference between means. Furthermore, multivariate analyses were used to classify 31 North African genotypes according to their STI values of 26 agro-morphological traits using the XLSTAT software v 7.5 (Addinsoft, USA). A standardized principal component analysis (PCA) was performed on the correlation matrix of the synthetic variable based on the STI values. To represent the relationships between studied genotypes in salt conditions, cluster analysis was performed to generate phenograms based on the Euclidean distance matrix of dissimilarity, calculated using all PCA scores, by the Ward method.

Conclusion

In this study, a wide variation in salt tolerance was found within barley landraces. Yield and growth traits showed increases or decreases in their performance, compared to the control or they would not be affected at all, depending on the genotype at moderate salt treatment. Conversely, high salinity generally decreased almost all measured phenotypic traits except for some specific salt-tolerant genotypes. It was also observed that the univariate analysis did not discriminate between putatively tolerant and susceptible genotypes differently with the PCA and hierarchical cluster analysis.

The phenotypic assessment-based approach highlighted a set of high-yielding landraces ranked as the most productive (Tozeur2, Tichedrett, Kerkena and Kebelli2), as also on the other hand, a set of high salt-tolerant ones with high grain yield STI values (Saida, Early1, Tichedrett, Azrir and Giza125), where Tichedrett showed the best performance with regard to both grain yield production as well as salt tolerance level. Such North African elite genotypes identified here, which come from adverse environments characterized by arid climate and affected by soil salinity, constitute a potential germplasm for breeding programs suitable for increasing barley production in saline areas. This strategy also enables barley production with saline water, without any undesirable effect on crop yield.

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