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# Phenotypic Diversity Analysis for Salinity Tolerance of Tunisian Barley Populations (*Hordeum vulgare* L.)

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**Abstract:** Salinity is one of the major constraints limiting the yield of barley (*Hordeum vulgare* L.) in Tunisia especially local barley. During 2010, a total of one hundred and twenty accessions collected from four regions were evaluated in a field conditions in two contrasting environments; rain fed and irrigated with high water salinity respectively using an augmented design model. In rain fed conditions, PCA discriminate the local barley according to their end use; Souihli and Arbi landraces as fodder barley and Ardhaoui landraces as food and feed. In salinity conditions, Ardhaoui population originally collected from low altitude (Zarzis, Medenine and Ben Guerden) is a salt tolerant landrace and display differential mechanisms for salt tolerance. Zarzis and Medenine landraces displayed a high biomass and high seed number suggesting that tolerance is due to an efficient seed translocation. The Ben Guerden landrace displayed a high harvest index and early flowering date suggesting that the tolerance is due to maintenance of low floral abortion. These results are prerequisite for developing tolerant varieties by crossing the best accessions possessing a good biomass and high fertility with accessions showing a high harvest index.

**Key Words:** Barley, Diversity, Evaluation, Landrace, Salinity

## 1. Introduction

Tunisia is essentially represented by arid and semi arid regions characterized by variable winter rainfall. The intra and inter-annual irregularity of rainfall led to the use of saline water for supplemental irrigation. Salt water concentration in dams and wells are 2 to 6 gr/l and 4 to 7 g/l respectively. In some cases water in wells can reach 10 gr/l salt concentrations especially in the South of Tunisia. Soil salinity is often the result of intensive agriculture (irrigation, fertilization, etc.) poorly controlled, resulting to a cumulative deposit of salts over years and gradually making land unfit for cultivation (Levigneron *et al*., 1995). In Tunisia, it is estimated that saline soils cover over 1,800,000 hectares (Slama, 2004).

Barley production in southern Tunisia is insufficient to satisfy the needs of humans and animals that constitute a major socio-activity of the population in the south (El Felah and Medimagh, 2005). Despite the importance of barley as a feed source, it remains a marginalized crop. In fact, local varieties that are well adapted to production systems in this region are far to satisfy the increased demand for feed and food. Therefore, to improve the productivity, it is necessary to search adaptation of barley accessions to salinity and exploit the available genetic variation for its introgression in cultivated varieties.

The objective of this study was to identify from a collection of 120 barley accessions the most tolerant genotypes to salinity after analysis of their agronomic performance in rain fed and irrigated field conditions with high water salinity.

## 2. Materials and Methods

### 2.1. Experimental Materials

A collection of one hundred and twenty barley accessions (*Hordeum vulgare* L. ssp. *vulgare*) collected in 2008 from fourteen localities of four provinces of Tunisia (Kairouan, Gabes, Medenine and Mahdia) by the National Gene Bank was used (**Table 1**).

### 2.2. Experimental sites

All of accessions were sown in the field with two contrasting environments: South (Medenine) and North of Tunisia (Mateur) on December 5 and 22, 2009 respectively. The trial was conducted in mixed model augmented design with six blocks and five modern cultivars as checks. Each accession was sown in a square meter area (1 × 1 m) i.e. 5 lines spaced 25 cm. Barley sown in site of Medenine is irrigated with saline water with a drip system. The water irrigation contains 6 gr/l of salt (8.06 ms/cm).

### 2.3. Agromorphological analysis

Barley plants have been monitored at three development stages: at 2 nodes, anthesis and maturity. The phenotypic

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**Table 1. Provinces, Regions, GPS coordinates, number of barley accessions and given name by farmers.**

| Provinces | Regions | Longitude | Latitude | Altitude (m) | Number of accessions | Name of population |
|---|---|---|---|---|---|---|
| Kairouan | Nadour | 38° 03’ N | 10° 08’ E | 114.9 | 10 | Arbi |
| Kairouan | ElGfai | 36°05’ N | 10° 14’ E | 73 | 10 | Arbi |
| Kairouan | Sisseb | 36° 00’ N | 10° 14’ E | 51 | 10 | Arbi |
| Gabes | Menzel hbib | 34° 19’ N | 9° 70’ E | 69-72 | 10 | Safra (2 row) |
| Gabes | Elmzaraa | 33° 88’ N | 9° 73’ E | 33-35 | 7 | Ardhao ui |
| Gabes | Soukra | 34° 01’ N | 9° 66’ E | 37 | 3 | Ardhaoui |
| Gabes | Toujane | 33° 69’ N | 9° 98’ E | 126 | 8 | Ardhaoui |
| Gabes | Mareth | 33° 63’ N | 10° 05’ E | 124 | 2 | Ardhaoui |
| Medenine | Medenine | 33° 60’ N | 10° 40’ E | 8 to 11 | 2 | Ardhaoui |
| Medenine | Zarzis | 33° 40’ N | 11° 08’ E | -1.76 | 7 | Ardhaoui |
| Medenine | Ben Guerden | 10° 08’ N | 14° 25’ E | 1.4 | 6 | Ardhaoui |
| Gabes | Matmata | 33° 21’ N | 11° 16’ E | 190 | 9 | Ardhaoui |
| Gabes | Toujane | 33° 42’ N | 10° 21’ E | 164 | 6 | Ardhaoui |
| Mahdia | Ksas | 35° 49’ N | 11° 02’ E | 0.2 | 18 | Souihli |
| Mahdia | Boumerdes | 35° 27’ N | 10° 43’ E | 77 | 4 | Souihli |
| Mahdia | Lahkayma | 35° 28’ N | 10° 54’ E | 0.4 | 2 | Souihli |
| Mahdia | Chorbene | 35° 30’ N | 10° 34’ E | 50 | 6 | Souihli |

evaluation was performed on eleven agronomic parameters: height (H), leaf Area (LA), days to flowering (FD), tiller number (TN), harvest index (HI), spike number (SN), biological yield (BY), grain number (GN), grain yield (GY), thousand seeds weight (TSW), percentage of fertile spikelet’s (PFS).

At 2 nodes and anthesis stages, five plants were taken randomly from each experimental unit to perform the analysis. Height (cm) is measured for the main axis from the basis of tillering to the end of the spike. The F3 leaf of main axis of five plants was scanned and the measurement of leaf area was calculated by an application “Mesurim_pro_29_03_10”. For biomass calculation, each plant was dried for 48 hours at 80°C and weighted. A random 0.25 m was used for measurement of yield and yield components. Spikes and straw were dried for 48 hours at 80°C.

### 2.4. Statistical analyses

Error variance was based on variance of the checks between plots and the values were adjusted regarding fixed model using SAS software V9.0.

## 3. Results and Discussion

### 3.1. Yield variation

The average grain yield of both sites was 2.57 tons/ha (**Table 2**). This performance was better than the national average yield in 2009 and 2008 which was about 0.75 and 0.8 tons/ha respectively (DGPA, 2009). Grain yield ranged from 0.43 to 0.58 tons/ha. The biological yield varied significantly from 0.3 to 2 tons/ha with an average of 0.85 tons/ha. These fluctuations in grain and biological yields were due to the effect of sites and genotypes.

**Table 2. Descriptive Statistical Analysis for yield components in two sites of experiment.**

| | $SN/m^2$ | $GN/m^2$ | TSW | PFS | BY Ton/ha | GY Ton/ha |
|---|---|---|---|---|---|---|
| Min | 0 | 1054 | 0,0 | 37.8 | 0.3 | 0.43 |
| Max | 572 | 15006 | 78.7 | 100 | 2 | 5.76 |
| Means | 282 | 6007 | 43.5 | 79.79 | 0.35 | 2.67 |
| Mateur | 317 | 7259 | 40,51 | 75.29 | 1.34 | 2.85 |
| Medenine | 248 | 5205 | 46,70 | 77.82 | 0.58 | 2.45 |

SN: Spike Number, GN: Grain Number, BY: Biological Yield, GY: Grain Yield, TSW: Thousand Seed Weight, PFS: Percentage of fertile spikelet’s

The average of grain yield at Medenine and Mateur sites were 2.45 and 2.85 tons/ha respectively with a standard deviation about 1.7 and 1.5 tons/ha. The grain yield in Medenine was 14% reduced compared to Mateur site. The SN, BY, GN, and spikelet’s fertility were reduced to 21.7; 34.5; 28.3 and 18.9% respectively while the grain filling in Medenine was better than in Mateur ( more than 13.2%)

### 3.2. Variance analysis

Results obtained from mixed model analysis indicated significant differences between accessions for ten and six traits among eleven for Medenine and Mateur sites respectively (**table 3**). Significant differences in Medenine sites for

**Table 3. Variance analysis estimates for 2 sites Medenine and Mateur of eleven quantitative traits.**

| Traits | Medenine | Mateur |
|---|---|---|
| H | 118.54047 ** | 122.1055 ** |
| LA | 287783.38 ns | 126562.8 * |
| FD | 165.97* | 27.2879* |
| TN | 5.7413 * | 7.668 ** |
| BY | 26741.814 * | 40665.4 ns |
| SN | 8.9852 ** | 17593.7 ns |
| GY | 33675.59 * | 79316.37 ** |
| HI | 0.342** | 0.147 ns |
| PFS | 8.985 ** | 17.73 * |
| TSN | 6.15 ** | 4944.23 ns |
| TSW | 59.14 * | 25.15 ns |

H: Height, LA: Leaf Area, FD: Days to flowering, TN: Tiller Number, BY: Biological Yield, SN: Spike Number, GY: Grain Yield, HI: Harvest Index, PFS: Percentage of fertile Spikelet's, TSN: Total Spikelet's Number and TSW: Thousand Seeds Weight.

*, ** difference significant at P= 0.05 level and P=0.01 respectively; ns= no significant

height, flowering date, tiller number, spike number, harvest index, biological yield, grain yield, percentage of fertile spikelet's total spikelet's number and thousand seeds weight were observed. No significant difference for leaf area. Only six criteria presented significant differences between accessions in Mateur site (H, LA, FD, TN, GY and PFS).

### 3.3. Principal component analysis

The Principal Component Analysis (PCA) based on all the variables was used for discrimination between genotypes. In the environment of Mateur, PCA represented 70% of variability (**Fig. 1**). The parameters; biological yield, grain yield, spike number and height explained 39% of the variability whereas PCA2 was influenced by leaf area, Tiller number, flowering date and fertile spike with 31% of variability.

This PCA separated the accessions according to their end use; i) The Ardhaoui landrace originated from the South is destinated for feed and food barley and is divided in two subgroups. First subgroub was characterized by their aptitude for seed production instead of biomass (Mareth, zarzis, Medenine). The second subgroup was known for their precocity, dwarfness, and weak leaf area (Ben Guerden, Alamette, Soukra) because they were naturally selected for their adaptation to drought (Ould MED Mahmoud *et al*., 2009; Hamza *et al*., 2004). In Menzel Hbib regions, farmers use also the two rowed type barley population called Safra and it's also feed and food barley. ii) The accessions of Center and Littoral called respectively Arbi and Souihli landraces are fodder barley and characterized by tall straw, high leaf area,

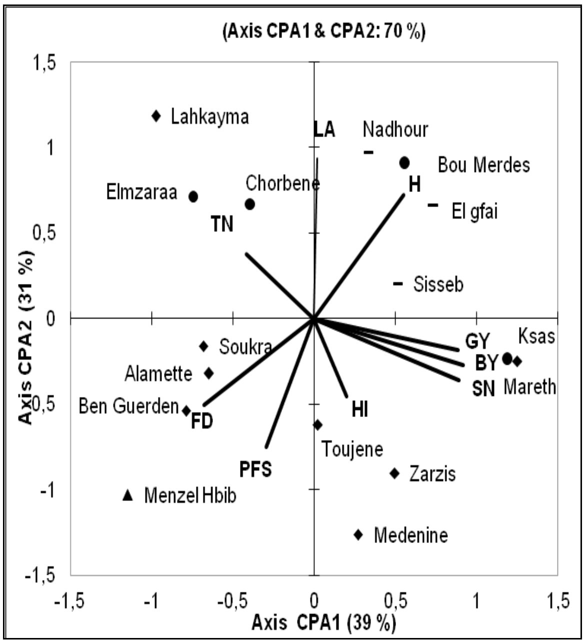


**Fig. 1. Principal component analysis in rain fed site: Accessions distribution according to the origin of collect.**
▬ : Population Arbi ▲: Population Safra
● : Population Souihli ◆ : Population Ardhaoui

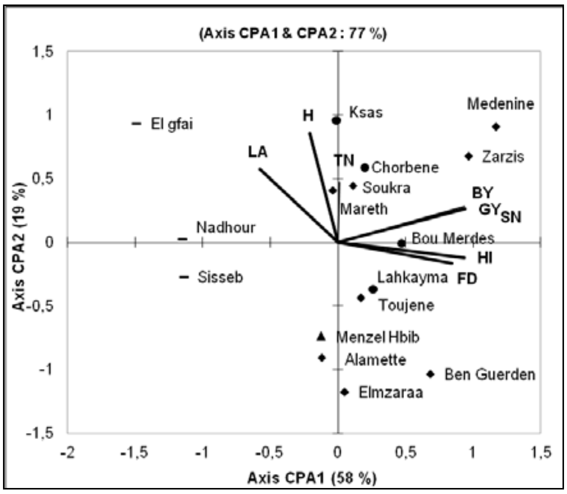


**Fig. 2. Principal component analysis for Medenine site: Accessions distribution according to the origin of collect.**
▬ : Population Arbi ▲ : Population Safra
● : Population Souihli ◆ : Population Ardhaoui

high tiller number and late heading date.

At the environment of Medenine, PCA showed that PCA 1 and PCA 2 axis explained 77 % of the total variability (**Fig. 2**). Biological yield, grain yield, seed number, harvest index and precocity expressed by flowering date are the best discriminating parameters for the PCA1 axis that explained 58 % of the total variability. The axis PCA 2 represents 19 % of the total variability and it is influenced by leaf area and height.

The PCA could distinguish 3 groups, two of them in the right side which suggest good adaptation to salinity as shown by a good yield. The first group (in the upper part) is composed essentially of Ardahoui landraces collected from Zarzis and Medenine that have an altitude less than 1.76 m and 8 to 11 m respectively and characterized by high salinity soil concentration. At Medenine environment, these accessions maintained high grain yield. Therefore, maintenance of good grain yield and a high seed number in high salt soil concentration could be a mechanism of tolerance to salinity. The second group in composed by Ksas and Ben Guerden accessions (altitude 0.2 and 1.4 m respectively) that was moderately salt sensitive accessions. The accessions collected from Ben Guerden were characterized by high harvest index and early heading date. Therefore precocity and a conservation of fertile spikelet's resulting in rapid seed translocation and high harvest index would contribute to salinity tolerance. In salinity conditions, population originally collected from low altitude (less than 11 m) was a salt tolerant population. This result confirms the result of the evaluation for salt tolerance in pots of eight Tunisian accessions by Cheikh M'Hamed *et al*. (2008).

The third group is composed by Arbi population. This population was salt sensitive barley and could be cultivated only in non salt soil (North and Center of Tunisia) as folder destination.

## 4. Conclusion

Current study detected high phenotypic variation in barley accessions among regions suggested that Tunisian barley landraces strongly influenced by environmental factors and acquired a natural adaptation. The degrees of variation of characters differ with regions from where the accessions are collected.

This work is a preliminary study towards the identification of mechanisms of tolerance to salinity of local barley. Different mechanisms of Souihli and Ardhaoui landraces were observed which suggest that this material could be used in breeding programs by crossing the best genotypes possessing a good biomass and high fertility with accessions showing a high harvest index.

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