Research & Reviews: Journal of Botanical Sciences
e-ISSN:2320-0189
p-ISSN:2347-2308

# Evaluation of Moisture Deficit in Spring Barley Landraces North West of Iran

**Sediqe Mahmoodpur[1], Ali Reza Eivazi[2*], Kamalsadat Asilan[3] and Cirous Mansourifar[3]**

[1]Department of Agronomy, Payamnour University, Karaj Branch, Iran

[2]Seed and Plant Improvement Research Department, West Azerbaijan Agricultural and Natural Resources Research and Education Center, AREEO, Urmia, Iran

[3]Agricultural Faculty of Payamnour University, Karaj Branch, Iran

## Research Article

Received: 27/06/2017
Accepted: 29/06/2017
Published: 30/06/2017

***For Correspondence**

Ali Reza Eivazi, Assistant Professor of Seed and Plant Improvement Research Department, West Azerbaijan Agricultural and Natural Resources Research and Education Center, AREEO, Urmia, Iran. Telephone: +989141451570.

**E-mail:** alirezaeivazi@yahoo.com

**Keywords:** *Barley landraces,* Drought tolerance indices, Multivariate analysis

**Abbreviations:** GMP: Geometric Mean Productivity, SSI: Stress Susceptible Index, STI: Stress Tolerance Index, TOL: Tolerance Index, HAR: Harmonic Index, MP: Mean Productivity.

**ABSTRACT**

An experiment was carried for evaluating the effects of moisture deficit at different growth stages in spring barley landraces under field conditions. A split plot experiment was conducted based on randomized complete blocks design with three replications. Three irrigation levels including optimal and disruption irrigations at stem elongation and heading were arranged as main plots and barely landraces with names of Abdolalikandy, Bastam, Sefid, Seyah, Shin, Hashtpar and Bayramghalasi were in subplots. Different irrigation levels and barley landraces for measured traits showed statistically significant differences. Grain yield under optimal, disruption irrigations at stem elongation and heading were 161.14 g/m2, 99.8 g/m2 and 128.0 g/m2, respectively. Shin and Hashtpar landraces with the lowest grain yield 88.75 g/m2 and 95.91 g/m2 and amounts of the least TOL 12.5, 0.59 and SSI 5.0, 0.75 at both stresses were tolerant to moisture deficit. Spike/m2 remained at final models in regression analysis at two moisture deficits. In principal components analysis, three first components explained more than 91% of total variance which they were named grain yield, physiological and morphological components, respectively. Grain yield was positively significant correlated with spike/m2 under optimal and disruption irrigations at stem elongation and heading with 0.94**, 0.90** and 0.94**, respectively. In both stresses, STI, MP, GMP and HAR indices had significant positive correlation with grain yield. In addition, spike/m2 and plant height had the most direct effects on grain yield 0.84 and 0.29, respectively.

## INTRODUCTION

Barley (*Hordeum vulgare* L.) is the most important cereal in worldwide which production in severely limited by moisture deficit in many production areas, and Iran don't exception from this rule [1]. Moisture deficit represents a complex quantitative trait determined by a multitude of genes which depends on the composition of a given population, plant growth stage, environmental conditions and other factors [2]. There several definitions of drought depending on different points of view. From a meteorological point, drought means lack of precipitation with respect to average values at a given time period. From a physiological point, drought means an imbalance in the plant water regime resulting in an excessive evapo-transpiration by aerial organs over water uptake by root [3]. According to the plant phonological phase affected by drought, three types of drought stress can occur: (1) pre-flowering water deficit (2) grain-filling water deficit (3) continuous water deficit with suited on 37 durum wheat landraces of Iran and Azerbaijan reported that under drought stress conditions there were positive significant correlations between grain yield and fertile tiller number at per plant, spike length, awn length and number of grains at per spike [4]. Revaluating twenty bread wheat genotypes reported that genotypes have higher genetic diversities for grain yield, spike number at per square meter, number of

e-ISSN:2320-0189
p-ISSN:2347-2308

grain at per spike, spike density and awn length [5]. Adverse effects of moisture deficit on growth and grain yield depend on time of tension, intensity stress, developmental stage and type of genotype in evaluating twenty-four durum wheat lines under moisture stress and non-stress conditions concluded that grain yield from indirect selection based on drought tolerance indices could improve grain yield than selection from non-moisture stress conditions [6,7]. Severity stress at the end-season of growth stage may be resulted to escape from harmful effects of water deficit at earlier genotypes [8,9]. The amount of grain yield reduction as a result of moisture deficit is affected by the stage of grain development where early grain development stage is more injury than latter grain development stage [10].

In study of barley varieties to drought imposed at different developmental stages showed that some genotypes could as a potential source of genes to drought tolerance stress [11]. Clarke used SSI to assess drought tolerance in wheat genotypes and found year-to-year variations in SSI for genotypes and could rank their pattern [12]. Crops expose to various unfavorable environmental conditions during their lives which is a significant effect on the growth [13]. It is a difficult challenge to achieve genetic improvement in the yield under these environments while progress in productivity has been much higher in favorable environments [14]. Thus, drought indicators which provide a measure of drought based on yield loss under drought stress conditions in comparison to normal conditions have been used to identify tolerant genotypes [15]. Barley especially its landraces is rather well-tolerant to moisture stress, therefore the objectives of this study were (I) to determine the most tolerant of barley landraces with the highest grain yield in the climate of the West Azerbaijan province, (II) identify of the endemic genetic resources compatible to region, (III) investigate the effect of moisture deficit on grain yield and its components under three conditions of optimal irrigation, disrupting of irrigation at stem elongation and heading stages.

## MATERIALS AND METHODS

A field experiment was performed in the spring of 2015 at 500 $m^2$ in fallow land with geographical coordinates 36˚, 44', 26" northern and 46˚, 29', 17.2" eastern from 9.5 km of North West of Shahindezh. A split plot experiment based on complete blocks design was carried out with 4 replications. The main plots include 3 levels of the optimum irrigation and moisture deficit in the stem elongation and heading stages growth and sub plots include 7 spring barley landraces with names of Abdolalikandi, Bastam, White, Black, Shin, Hashtpar and Bayramghalasi. Each block includes 21 plots with 3 $m^2$ at four rows. Plant density was in 400 seed/$m^2$. Seeds were sown in mid of March and then irrigated. Weeds were controlled with hand by removing them. The husbandry operations were done separately for each plot. For measuring traits of total dry mater and grain yield total plots were harvested at the end season.

Evaluated traits were chlorophyll content, spike length, spike number per square meter, number of grains per spike, 1000-kernal weight, grain yield, flag leaf area, total dry matter, plant height, relative water content and harvest index.

**Chlorophyll content:** Six leaves were collected from each plot measured by chlorophyll meter [16].

**Plant height, spike length, number of grains at per spike:** Five plants were randomly selected from each plot and their lengths were measured and averaged [17].

**Spike number at per square meter:** The produced spikes in each sample were counted per unit area. 1000-kernal weight: after harvesting, 250 grains were counted and weighted then calculated based on 1000 ratio. Harvest index: is the ratio of grain yield to total dry matter [17].

**Relative water content:** The wet weight of 6 leaves were measured and placed in distilled water. After 12 hours, the turgor weight and dry weight of samples obtained and calculated based on following formula:

The relative water content (%)=(wet weight- dry weight)/(turgor weight–dry weight) × 100

**Flag leaf area: i**s calculated with measuring length and width of leaf according to the following formula [18].

The flag leaf area=length of flag leaf × width of flag leaf × 0.7

### Statistical Analysis

Analysis of variance for traits which was recorded under field conditions was done with Mstat-C soft-ware. Means were compared with Duncan's multiple range tests at 0.05 probability level. Also, simple correlation coefficient, regression analysis, path analysis and principal component analysis was done with SPSS soft-ware. Stress tolerance indices were calculated as below formulas:

GMP= $\sqrt{}$ (Ys)(Yp),

SSI=1-[Ys-Yp]/SI and SI=1-[Ys/Yp],

STI=(Ys)(Yp)/(Yp)2,

TOL=Yp-Ys,

HAR=2(Yp.Ys)/(Ys+Yp),

MP=(Yp+Ys)/2,

Yp and Ys were aerial organ weight at control and stress conditions, respectively [19-22].

## RESULTS AND DISCUSSION

Results analysis of variance showed that there were significant differences for traits of spike length, spike number per square meter, number of grains at per spike, 1000-kernal weight, grain yield and total dry matter under moisture deficit ($P \leq 0.01$). For except of relative water content, genotypes had showed significantly difference at all traits. In addition, spike length was significant difference at interaction between moisture deficit and genotype **(Table 1)**. The success of any selection or hybridization breeding program for developing drought tolerant varieties depends on precise estimates of genetic the variation components for traits [23,24]. In our experiment were seen variations between genotypes under stress which could be used in breeding programs. By evaluating 20 bread wheat genotypes reports that genotypes have higher genetic diversities for grain yield, spike number per square meter, number of grain per spike, spike density and awn length in comparison with other traits.

**Table 1.** means squares for traits of barley landraces under field conditions.

| SOV | df | Plant height | Chlorophyll | Flag leaf area | Spike length | Spike/m² | Grain/ Spike | 1000-kernal weight | Grain yield | Total dry matter | Harvest Index |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Replication | 3 | 15.1 | 143.3 | 1168.8 | 0.1 | 16955.1 | 2.7 | 32.7 | 15072.2 | 21904.7 | 746.6 |
| Stress | 2 | $3.3^{ns}$ | $35.9^{ns}$ | $8856.1^{ns}$ | $4.5^{**}$ | $56174.2^{**}$ | $61.0^{**}$ | $422.9^{**}$ | $26630.6^{**}$ | $110442.4^{**}$ | $39.8^{ns}$ |
| Error | 6 | 28.5 | 12.9 | 4495.0 | 0.1 | 898.3 | 3.0 | 30.8 | 1019.5 | 1636.9 | 94.4 |
| Genotype | 6 | 136.9 | $135.5^{**}$ | $8829.0^{*}$ | $12.4^{**}$ | $30660.9^{**}$ | $6.6^{**}$ | $130.3^{**}$ | $15972.1^{**}$ | $35684.5^{**}$ | $636.4^{**}$ |
| Effective | 12 | $9.2^{ns}$ | $28.5^{ns}$ | $1603.3^{ns}$ | $2.9^{**}$ | $3305.8^{ns}$ | $1.2^{ns}$ | $9.3^{ns}$ | $1423.0^{ns}$ | $3883.9^{ns}$ | $62.4^{ns}$ |
| Error | -- | 9.1 | 39.9 | 3454.7 | 0.1 | 1956.2 | 1.9 | 17.2 | 1028.5 | 3253.9 | 132.7 |
| CV(%) | 54 | 5.2 | 17.1 | 36.9 | 2.5 | 21.1 | 11.1 | 8.0 | 24.7 | 19.9 | 25.1 |
| ns, * and **: don't significant differences, significant at 0.05 and 0.01 probability levels, respectively. | | | | | | | | | | | |

### The Chlorophyll Content

White barley had the most chlorophyll content of 41.56% **(Table 2)**. Black barley, Shin, Hashtpar and Abdolalikandi were arranged at the next group, respectively. Also, Bastami (32.6%) and Byramghlasi (33.8%) had the least chlorophyll content. Amount of variation range between the most and least chlorophyll content of genotypes was 8.95%. Important physiological parameters such as chlorophyll content associated with moisture deficit tolerance. Researchers proved varieties which had high amounts of this trait had better grain yield, and higher total dry matter under drought stress conditions in genetic analyzing of barley genotypes under moisture deficit observed significant difference for trait of leaf chlorophyll content between genotypes and two quantitative trait loci were detected for leaf chlorophyll content [25].

**Table 2.** Mean comparison for traits of barley landraces under field conditions.

| Genotype | Grain yield (gr/m²) | 1000-kernal weight (gr) | Grain/spike | Spike/m² | Chlorophyll (%) | Plant height (cm) | Total dry matter (gr/m²) |
|---|---|---|---|---|---|---|---|
| Bayramghalasi. | $148.3^{b}$ | $53.4^{ab}$ | $11.8^{b}$ | $264.8^{a}$ | $33.8^{cd}$ | $55.7^{b}$ | $291.6^{c}$ |
| Abdolalikandi | $150.0^{b}$ | $48.53^{cd}$ | $13.0^{ab}$ | $225.2^{b}$ | $35.3^{bcd}$ | $57.1^{b}$ | $300.0^{bc}$ |
| White | 180.0a | $51.5^{bc}$ | $12.5^{b}$ | $254.4^{ab}$ | $41.5^{a}$ | $65.1^{a}$ | $341.6^{ab}$ |
| Black | $95.8^{c}$ | $50.5^{bcd}$ | $12.7^{ab}$ | $165.1^{c}$ | $40.4^{ab}$ | $58.1^{b}$ | $287.5^{c}$ |
| Shin | $88.7^{c}$ | $56.7^{a}$ | $11.8^{b}$ | $139.9^{c}$ | $38.6^{abc}$ | $56.5^{b}$ | $204.1^{d}$ |
| Bastam | $152.5^{b}$ | $47.2^{d}$ | $13.8^{a}$ | $248.3^{ab}$ | $32.6^{d}$ | $56.0^{b}$ | $350.0^{a}$ |
| Hashtpar | $92.9^{c}$ | $53.7^{ab}$ | $11.9^{b}$ | $168.4^{c}$ | $36.2^{abcd}$ | $55.4^{b}$ | $225.0^{d}$ |
| Means with the same letter(s) don't have significant differences with multiple range test at 0.05 probability level. | | | | | | | |

### The Spike Number at Per Square Meter

Bayramghalasi (246.8) and Shin (139.9) had the most and the least spike number at per square meter **(Table 2)**. Abdolalikandi characterized at the second group. White and Bastam located in the same group. Spike number at per square meter was affected by different levels of moisture deficit. With increasing severity of stress amount of this trait decreased consequently. Regardless of genotype, spike number at per square meter in optimal conditions, stem elongation and heading stage stresses were obtained 252.6, 212.5 and 163.2, respectively **(Table 3)**. Reported that cereal crops produce the highest grain yield by applying irrigation at all definable growth stages. Because irrigation is an expensive input and need to know the response of yield to irrigation. The reactions of plants to water stress differ significantly at various organizational levels depending upon intensity and duration of stress as well as plant species and its stage of growth [26,27].

e-ISSN:2320-0189
p-ISSN:2347-2308

**Table 3.** Mean comparison for traits of barley landraces under different moisture deficits.

| Stress | Grain yield(gr/m$^2$) | 1000-kernal weight(gr) | Grain/spike | Spike/m$^2$ | Spike length(cm) | Total dry matter(gr/m$^2$) |
|---|---|---|---|---|---|---|
| Normal | 161.4$^a$ | 55.1$^a$ | 14.1$^a$ | 252.6$^a$ | 16.2$^a$ | 344.6$^a$ |
| Heading | 128.0$^b$ | 52.6$^b$ | 12.3$^b$ | 212.5$^b$ | 15.4$^c$ | 292.8$^b$ |
| Stem elongation | 99.8$^c$ | 47.5$^c$ | 11.1$^c$ | 163.2$^c$ | 16.0$^b$ | 219.6$^c$ |

Means with the same letter(s) don't have significant differences with multiple range test at 0.05 probability level.

### Grain Per Spike

The most and lowest grain per spike were allocated for Bastam and Bayramghalasi, Shin with 13.8 and 11.8, respectively **(Table 2)**. Different levels of moisture deficit reduced grains at per spikes, so that moisture deficit at stem elongation stage had the least amount (11) **(Table 3)**. In evaluating durum wheat landraces demonstrated that grain yield had positive and significant correlation with number of grains at per spike. Several researchers reported that the yield components like grain number were decreased at pre-anthesis drought stress in wheat [28,29].

### 1000-Kernal Weight

Shin and Bastam showed the highest and lowest 1000-kernal weight with 56.7 g and 47.2 g respectively **(Table 2)**.

1000-kernal weight at optimal irrigation and heading stage stress was more than 50 g and at stem elongation stage stress was less than 50 g. Stated that the 1000-kernal weight of wheat and barley was decreased due to the moisture deficit. Agro-morphological traits have a special role to determine the importance of each trait on increasing yield, as well as to use those traits at the breeding programs, which at least lead to improving yield and introducing commercial varieties under end seasonal drought stress conditions [30-33].

### Grain Yield

Average grain yield of genotypes at moisture deficit in heading and stem elongation stages were less than 150 g/m$^2$ and 100 g/m$^2$, respectively **(Table 3)**. Researches reported that drought stress reduced grain yield and was estimated average yield loss was between 17% to 70%. Stress severity in moisture deficit at stem elongation stage was 38.16%. Response of plants to moisture deficit depends on several factors, such as developmental stage, intensity and duration of stress and cultivar genetics.

The maximum and the minimum grain yield were produced by white barley and Shin with 180 g/m$^2$ and 88.75 g/m$^2$ respectively. The grain yield is a function of the number of spike at per unit area, number of grain at per spike and 1000-kernal weight and they affected by different levels of irrigation regimes. Spike at per square meter was the most important between main grain yield components. Therefore, grain yield could be increased by increasing spike and fertile tillering at per square meter.

### Flag Leaf Area

Shin due to has the most flag leaf area (204.3 mm$^2$) is suitable for fodder production and Bayramghalasi has the least flag leaf area (115.6 mm$^2$) is unsuitable for animal nutrition **(Table 2)**.

### Total Dry Matter

Bastam barley and Shin have assigned the most and the least total dry matter of 350 g/m$^2$ and 204.16 g/m$^2$, respectively **(Table 2)**. The total dry matter for all landraces was decreased under the moisture deficit. Put on stress was more severity in the stem elongation stage and trend of it was more sensible. Range of variations between genotypes was 125 g/m$^2$ **(Table 3)**. Decreasing amounts of aerial organs during irrigation disruption has the effect on grain yield and total dry matter and consequently harvest index. The plant response is complex because it reflects over space and time the integration of stress effects and responses at all underlying levels of organization [34].

### The Plant Height

White, Black and Hashtpar genotypes were the highest, average and the shortest values with 56.1 cm, 58.1 cm and 55.4 cm, respectively. Drought stress is a very important limiting factor at the initial phase of plant growth and establishment. It affects both elongation and expansion growth. Morphological characters such as number of tillers, grain per spike number, 1000 grain weight, plant height, spike length, kernel number per spike, grain weight per spike affect the wheat tolerance to the moisture shortage in the soil [35-38].

### Harvest Index

White and Black barleys, had the maximum and minimum harvest index of 54.3% and 33.2%, respectively. Bayramghalasi, Abdolalikandi and Shin barleys were in the same group lower than white barley. Bastam and Hashtpar barleys with 42.5% and 41.0% were in the third group and higher than Black barley. The variety range was 21.0%. Considering the spike as the place of grain accumulation and the important removable part and also regarding to heading and plant entrance to reproductive stage and

e-ISSN:2320-0189
p-ISSN:2347-2308

need to water, a higher stress severity compared with stem elongation step is justifiable. Since the stage of pollen production and formation of ovule and finally pollination and grain production were the new evolutionary steps of plant, so the internal reactions of plant revealed more need to water and more damage to the plant which will affect the performance completely.

**The Spike Length**

Interaction between growth conditions and genotype for trait of spike length was statistical and significantly difference ($p \leq 0.01$). Drought tolerance consists of ability of crop to growth and production under water deficit conditions. A long-term drought stress effects on plant metabolic reactions associates with, plant growth stage, water storage capacity of soil and physiological aspects of plant. Achieving a genetic increase in grain yield under these environments has been recognized to be a difficult challenge for plant breeders while progress in yield grain has been much higher in favorable environments. Also, the results of this research represented that moisture deficit causes low grain yield and in moisture deficit conditions chlorophyll content, length spike, spike number per square meter, number grains per spike, 1000-kernal weight, grain yield, harvest index, flag leaf area, total dry matter, plant height had more susceptibility [39].

**Correlation Coefficients of Traits**

Under optimal growth conditions grain yield showed the highest positive significantly correlation with traits of spike number per square meter (r=0.94**), total dry matter (r=0.95**) and harvest index (r=0.82**). Moisture deficit under heading stage, only spike number per square meter (r=0.94**) had positively significant correlation with grain yield. Moisture deficit under stem elongation conditions grain yield displayed positively significant correlation (r=0.90**) with spike number per square meter **(Table 4)**. It should be noted that under three conditions of growth stages spike number per square meter was the most important trait Therefore it was revealed that this trait in all the studied spring barley land races can be the appropriate factor to select the best genotypes.

**Table 4.** Simple correlation coefficient of barley traits under three field conditions.

| | Traits | Chlorophyll | Spike length | Spike/ m2 | Grain/ Spike | 1000-kernal weight | Grain yield | Flag leaf area | Total dry matter | Plant height |
|---|---|---|---|---|---|---|---|---|---|---|
| Normal | Spike length(cm) | 0.20 | | | | | | | | |
| | Spike/ m2 | 0.18- | 0.29 | | | | | | | |
| | Grain/Spike | -0.27 | 0.64 | 0.59 | | | | | | |
| | 1000-kernal weight | 0.70 | -0.29 | -0.43 | -0.65 | | | | | |
| | Grain yield (gr/m2) | -0.03 | 0.49 | 0.94** | 0.75 | -0.43 | | | | |
| | Flag leaf area (mm) | -.022 | 0.15 | -0.36 | .038 | -0.50 | -0.17 | | | |
| | gr/m2 Total dry | -0.12 | 0.50 | 0.93** | 0.71 | -0.59 | 0.95** | -0.10 | | |
| | Plant height (cm) | 0.55 | 0.88** | 0.24 | 0.57 | 0.00 | 0.51 | 0.12 | 0.43 | |
| | Harvest index (%) | 0.19 | 0.40 | 0.76* | 0.63 | -0.05 | 0.87** | -0.25 | 0.69 | 0.57 |
| Heading | Spike length (cm) | 0.62* | | | | | | | | |
| | Spike/ m2 | 0.11 | -0.21 | | | | | | | |
| | Grain/Spike | -0.04 | 0.02 | -0.12 | | | | | | |
| | 1000-kernal weight | 0.12- | -0.13 | -0.22 | - | | | | | |
| | Grain yield (gr/m2) | 0. 10 | -0.01 | 0.94** | -0.09 | -0.17 | | | | |
| | Flag leaf area (mm) | 0.09 | 0.23 | - | -.022 | 0.56 | -0.83* | | | |
| | gr/m2 Total dry | 0.27 | 0.27 | 0.67 | 0.25 | -0.72 | .067 | - | | |
| | Plant height (cm) | 0.69 | 0.73 | 0.28 | -0.26 | 0.10 | 0.54 | -0.09 | 0.040 | |
| | Harvest index (%) | -0.19 | -0.37 | 0.60 | 0.27 | 0.43 | 0.66 | -0.36 | -0.10 | 0.22 |
| Stem elongation | Spike length (cm) | 0.33 | | | | | | | | |
| | Spike/ m2 | -0.62 | -0.05 | | | | | | | |
| | Grain/Spike | -0.40 | 0.51 | 0.31 | | | | | | |
| | 1000kernalweight(gr) Grain | 0.36 | -0.62 | -0.60 | -0.74 | | | | | |
| | yield (gr/m2) | -0.40 | 0.10 | 0.90** | 0.22 | -0.70 | | | | |
| | Flag leaf area (mm) | 0.63 | -0.03 | 0.86** | -0.36 | 0.61 | -0.71 | | | |
| | gr/m2 Total dry | -0.21 | 0.54 | 0.58 | 0.81* | - | 0.64 | -0.47 | | |
| | Plant height (cm) | 0.42 | 0.17 | 0.28 | -0.11 | -0.26 | 0.47 | -0.30 | 0.36 | |
| | Harvest index (%) | -0.30 | -0.42 | 0.63 | -0.48 | -0.53 | 0.69 | -0.46 | -0.09 | 0.30 |

**The Sensitivity Indices**

The indices of sensitivity regarding to the grain yield were SI=0.39 and S=0.21 stress severity under moisture deficit in the heading and stem elongation stages, respectively. In both stress, the trend changes and the order of genotypes were the same.

e-ISSN:2320-0189
p-ISSN:2347-2308

For TOL index, White and Bastam genotypes with the values of 70.0 and 67.5 had the most and genotypes of Shin and Hashtpar with the values of 12.5 and 5.0 had the least amounts. Abdolalikandi and Bayramghalasi with 51.2 and 18.7 for TOL index showed the average sensitivity in this index and other tolerance indices. The genotypes of Shin and Hashtpar with the lowest yield but with the minimum and desired TOL and SSI, are the most tolerant genotypes to the moisture deficit **(Table 5)**. Tolerance to abiotic stresses is very complex, due to the impact of interactions between stress factors and various molecular, biochemical and physiological phenomena affecting plant growth and development.

**Table 5.** Values of drought tolerance indices of barley land races.

| Stress | Genotype | STI | MP | GMP | SSI | TOL | HAR |
|---|---|---|---|---|---|---|---|
| Heading | Bayramghalasi | 1.0 | 169.3 | 169.1 | 0.5 | 18.7 | 168.8 |
| | Abdolalikandi | 1.0 | 166.8 | 164.8 | 1.2 | 51.2 | 162.9 |
| | White | 1.5 | 202.5 | 199.4 | 1.4 | 70..0 | 196.4 |
| | Black | 0.4 | 106.8 | 106.4 | 0.8 | 18.7 | 106.0 |
| | Shin | 0.3 | 93.5 | 93.5 | 0.5 | 12.5 | 93.3 |
| | Bastam | 1.0 | 172.5 | 169.1 | 1.5 | 67.5 | 165.8 |
| | Hashtpar | 0.3 | 101.2 | 101.2 | 0.7 | 5.0 | 101.1 |
| Stem elongation | Bayramghalasi | 0.7 | 142.5 | 137.8 | 1.0 | 72.5 | 133.2 |
| | Abdolalikandi | 0.8 | 154.3 | 149.5 | 1.0 | 76.2 | 144.9 |
| | White | 1.2 | 186.2 | 179.0 | 1.1 | 102.5 | 172.1 |
| | Black | 0.3 | 95.0 | 92.5 | 0.9 | 42.5 | 90.2 |
| | Shin | 0.30 | 89.37 | 88.74 | 0.56 | 21.24 | 88.11 |
| | Bastam | 0.89 | 159.37 | 152.32 | 1.17 | 93.75 | 145.58 |
| | Hashtpar | 0.28 | 87.50 | 86.77 | 0.58 | 22.50 | 86.05 |

**Correlation Coefficients of Indices**

Indices of STI, MP, GMP and HAR had the positive and significant with grain yield under moisture deficit in heading stage. So, these indices can be used as direct factor for screening tolerant genotypes. The highest correlation coefficient of grain yield under moisture deficit in the heading stage is related to Harmonic index (HAR) of 0.92 and the lowest positive and significantly index is related to Mean Production index (MP) of 0.85. Correlation coefficients of traits under moisture deficit in stem elongation stage showed that all sensitivity indices except SSI had the positive and significantly with grain yield. The main point is that TOL index under stress conditions in heading stage didn't have significantly correlation with grain yield and it seems that with increase of stress severity in the stem elongation stage the value of this index is important and this index could be used in the screening of tolerant genotypes to moisture deficit in the stem elongation stage **(Table 6)**. Also, reported that under moisture deficit, indices of MP, GMP, STI and HAR were positively significant correlations with grain yield and it was similar results of this study [40].

**Table 6.** Simple correlation coefficient of indices heading and stem elongation stages stresses.

| | Index | STI | MP | GMP | SSI | TOL | HAR | Yn |
|---|---|---|---|---|---|---|---|---|
| | MP | 0.99** | | | | | | |
| heading | GMP | 0.99** | 1.00** | | | | | |
| | SSI | 0.50 | 0.60 | 0.60 | | | | |
| | TOL | 0.89* | 0.90** | 0.90** | 0.77* | | | |
| | HAR | 0.99** | 0.96** | 0.96** | 0.39 | 0.81* | | |
| | Yn | 0.90** | 0.92** | 0.92** | 0.71 | 0.99** | 0.85* | |
| | Ys | 0.99** | 0.85* | 0.85* | 0.28 | 0.68 | 0.92** | 0.75 |
| Stem elongation | MP | 1.00** | | | | | | |
| | GMP | 1.00** | 1.00** | | | | | |
| | SSI | 0.89** | 0.89** | 0.89** | | | | |
| | TOL | 0.96** | 0.96** | 0.96** | 0.96** | | | |
| | HAR | 1.00** | 1.00** | 1.00** | 0.89** | 0.96** | | |
| | Yn | 1.00** | 1.00** | 1.00** | 0.89** | 0.96** | 1.00** | |
| | Ys | 0.85* | 0.85* | 0.85* | 0.67 | 0.82* | 0.85* | 0.85* |

**Multivariate Analysis**

In the regression analysis under optimal growth conditions traits of total dry matter, the harvest index and chlorophyll content had the highest coefficient with grain yield and remained in the final model [41,42]. The detection coefficient is $R^2$=0.93 which indicates good justification grain yield with above traits. Under moisture deficit in the heading stage, traits of spike number per square meter and plant height with 0.85 and 0.24 coefficients were remained in the final model. Under stress in the stem elongation stage, the spike numbers per square meter was the most important trait. In this study, spike number per square meter displayed the most positive and significantly coefficient under three growth conditions **(Table 7)**.

**Table 7.** Regression co-efficient of related traits of barley landraces under field conditions.

| Conditions | Model | Standard Coe | Un-standard Coe | Standard div | Probability level |
|---|---|---|---|---|---|
| Normal | Total dry matter | 0.638 | 0.446 | 0.008 | 0.000 |
| | Harvest Index | 0.445 | 3.291 | 0.087 | 0.000 |
| | Chlorophyll | -0.047 | -0.933 | 0.169 | 0.012 |
| | Constant | | | | $R^2$=0.93 |
| Heading | Spike/m$^2$ | 0.859 | 0.554 | 0.058 | 0.001 |
| | Plant height | 0.249 | 2.346 | 0.717 | 0.031 |
| | Constant | | | | $R^2$=0.97 |
| Stem elongation | Spike/m$^2$ | 0.908 | 0.781 | 0.162 | 0.005 |
| | Constant | | | | $R^2$=0.82 |
| Grain yield= -109.356+0.638 (Total dry matter)+0.445 (Harvest index)+(-0.047) (Chlorophyll)<br>Grain yield= -124.739+0.859 (Spike/m$^2$)+0.249 (Plant height) Grain yield= -27.72+0.908 (Spike/m$^2$) | | | | | |

Based on principal components analysis, at first component, traits of total dry matter, grain yield and spike number per square meter had the most coefficients of eigen values. White, Bastam were the highest and Shin, Hashtpar were the lowest coefficients in this component. In the second component, spike length, chlorophyll content and relative water content had the highest coefficients and White, Black genotypes had the highest amount. In third component plant height was the most coefficients which White genotype had the highest value. Totally, names of three main components can be knew grain yield, physiological and morphological traits, respectively. Also, each variance component was 45.12, 27.79 and 18.75, percentage, respectively **(Figure 1)**. And total cumulative variance percentage was 92.67% **(Table 8)**.

**Table 8.** Principal component analysis for stress tolerance indices of barley land races.

| Component | Eigen values | % Variance | Cumulative Proportion |
|---|---|---|---|
| 1 | 4.96 | 45.12 | 45.12 |
| 2 | 3.05 | 27.79 | 72.91 |
| 3 | 2.06 | 18.75 | 92.67 |

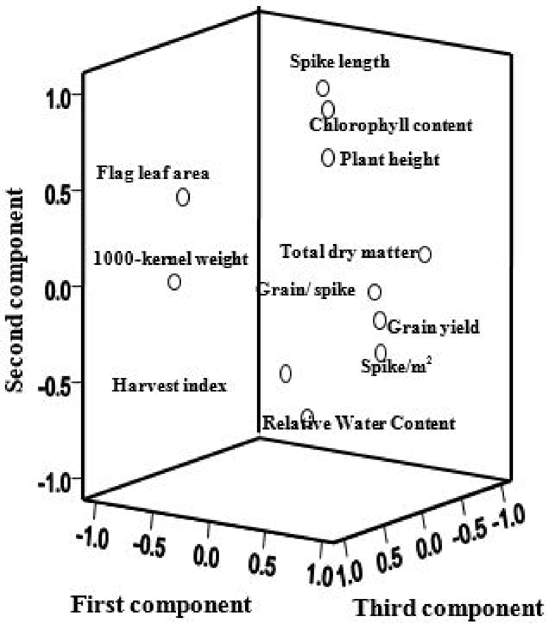


**Figure 1.** Schematic of three main components based on traits of barley genotypes.

Path analysis showed that two traits spike number per unit area and the plant height had the direct effects of 0.84 and 0.29. Trait of spike number per unit area had the relatively more correlation (0.93**) with the grain yield **(Table 9)**.

**Table 9.** Path analysis of based on the mean of traits.

| Traits | Direct effects | Indirect effect Spike/m$^2$ (X1) X1 | Indirect effect plant height (X2) X2 | Simple correlation with grain yield |
|---|---|---|---|---|
| Spike/m$^2$)X1) | 0.84 | - | 0.08 | 0.93** |
| Plant height) X2) | 0.29 | 0.25 | - | 0.54$^{ns}$ |

## CONCLUSION

The white and Bastam barleys had the most and Shin and Hashtpar had the least sensitivity to the moisture deficit. Black barley only was more sensitive than the least values and this trend was constant in all indices. Bayramghalasi and Abdolalikandi were intermediate. Shin and Hashtpar with the lowest grain yield but were the most tolerant landraces under moisture deficit (with the tolerant genes to moisture deficit) and they are recommended for regions with severe and longtime moisture deficit. White and Bastam with the most grain yield and most SSI and TOL were grouped as a sensitive and less tolerant to the moisture deficit and were appropriate for the regions with the mild stress. It can be noted that although Shin and Black barleys had the lowest grain yield, but due to having pigment in the grains displayed significant tolerance under three growth conditions. It seems that pigments can be considered as a genetic marker for screening tolerant genotypes to moisture deficit in breeding programs. In contrast, White barley with bright color had the highest grain yield and the most sensitivity to the moisture deficit. Number of spike at per square meter had the highest correlation with grain yield under three growth conditions. Therefore, it was the most direct effect on increasing grain yield, so this trait was important for selecting genotypes with high grain yield. One of the most important strategies in barley breeding program is introducing of new alleles from landraces such as our genotypes in to the promising lines. Shin and Hashtpar barley landraces from Shhindezh, Iran could be used in crossing programs due to have high moisture deficit tolerance based on seven indices. Breeding for moisture deficit stress remains a great challenge due to complex nature of the trait.

## REFERENCES

1. Ahmadizadeh M. Physiological and agro-morphological response to drought stress. Middle East J Sci Res. 2013; 13:998-1009.
2. Ahmadizadeh MA, et al. Effects of drought stress on some agronomic and morphological traits of durum wheat (*Triticum durum* Desf.) landraces under greenhouse condition. Afr J Biotechnol. 2011(a);10:14097-1410.
3. Ahmadizadeh MH, et al. Genetic diversity of durum wheat landraces using multivariate analysis under normal irrigation and drought stress conditions. Afr J Agric Res. 2011(b);6:2294-2302.
4. Ahmadizadeh, et al. Morphological diversity and interrelationships traits in durum wheat landraces under normal irrigation and drought stress conditions. Adv Environ Biol. 2011(c);5:1934-1940.
5. Al-Meselmani M, et al. Evaluation of physiological traits, yield and yield components at two growth stages 10 durum wheat lines growth under rainfed conditions in Southern Syria. Cercetări Agronomice în Moldova. 2015;2:29-49.
6. Clarke JM, et al. Evaluation of methods for quantification of drought tolerance in wheat. Crop Sci Society of America. 1992;32:723-728.
7. Collins NCF, et al. Quantitative trait loci and crop performance under abiotic stress: Where do we stand? Plant Physiol. 2008;147:469-486.
8. Dadbakhsh AA, et al. Study drought stress on yield of wheat (*Triticum aestivum* L.) genotypes by drought tolerance indices. Adv Environ Biol. 2011;5:1804-1810.
9. Daneshian J, et al. Drought stress effects on yield, quantitative characteristics of new sunflower hybrid. The Second International Conference on Integrated Approaches to Sustain and Improve Plant Production under Drought Stress. Roma. Italy. 2005; P: 406.
10. Edward D and Wright D. The effects of winter water-logging and summer drought on the growth and yield of winter wheat (*Triticum aestivum* L.). Eur J Agron. 2008;28:234-244.
11. Eivazi ARS, et al. Effective selection criteria for assessing drought tolerance indices in barley (*Hordeum vulgare* L.) accessions. Intl J Agron Plant Prod. 2013;4:813-821.
12. El-Kholy MA, et al. Predicting the interaction between the effect of anti-transpirant and climate on productivity of wheat plant grown under water stress. Journal of Agronomy. 2005; 4:75-82.
13. Eskandari H and Kazemi K. Response of different bread wheat (*Triticum aestivum* L.) genotypes to post-anthesis water deficit. Notulae Scientia Biologica. 2010; 2:49-52.
14. FAO. World Food and Agriculture. Statistical Yearbook. Food and Agriculture Organization of the United Nations. Rome. Italy. 2013.
15. Fernandez GCJ. Effective selection criteria for assessing plant stress tolerance. Kuo CG (eds) Adaptation of food crops to temperature and water stress. In Proc. Int. Symp, Taipei, Taiwan. 1992.
16. Fischer RA and Maurer R. Drought resistance in spring wheat cultivars. I. Grain yield responses. Aust J Agr Res. 1978;29:897-912.
17. Garavandi M and Kahrizi D. Evaluation of genetic diversity of bread wheat genotypes for phonologic and morphologic traits. The 11th Crop Sci and Plant Breeding Congress, Iran. 2010;537-541.

e-ISSN:2320-0189
p-ISSN:2347-2308


18. Gonzalez A, et al. Barley yield in water stress conditions. The influence of precocity, osmotic adjustment and stomatal conductance. Field Crop Res. 1999;62:23-34.

19. Habibpor MM, et al. Genetic diversity and correlation among agronomic and morphological traits in wheat genotypes (*Triticum aestivum* L.) under influence of drought. Adv Environ Biol. 2011;5:1941-1946.

20. Haddadin M, et al. Response of barely varieties to drought stress imposed at different developmental stages. Jordan Journal of Agricultural Sciences (JJAS). 2013;9:507-524.

21. Hugh JE and Davis F. Effect of drought stress on leaf and whole canopy radiation efficiency and yield of maize. Agron J. 2003;95:688-696.

22. Jaleel CAP, et al. Drought stress in plants: A review on morphological characteristics and pigments composition. Int J Agric Biol. 2009;11:100-105.

23. Jamaux IA, et al. Looking for molecular and physiological markers of osmotic adjustment in sunflower. Plant Physiol. 1997;137:117-127.

24. Kaman HC, et al. Genotypic differences of maize in grain yield response to deficit irrigation. Agric Water Manag. 2011;98:801-807.

25. Khayatnezhad MM, et al. Study of morphological traits of wheat cultivars through factor analysis. Am Eurasian J Agric Environ Sci. 2010;9:460-464.

26. Kristin AS, et al. Improving common bean performance under drought stress. Crop Sci. 1997;37:51-60.

27. Lichtenhaler HK. Vegetation stress: An introduction to the stress concept in plants. J Plant Physiol. 1996;148:4-14.

28. Mitra J. Genetics and genetic improvement of drought resistance in crop plants. Curr Sci. 2001; 80:758-762.

29. Mohammadi AA, et al. Genetic analysis of some agronomic traits in flax (*Linum usitatissimum* L.). Aust J Crop Sci. 2010;4:343-352.

30. Mollasadeghi V, et al. Classifying bread wheat genotypes by multivariable statistical analysis to achieve high yield under after anthesis drought. Middle East J Sci Res. 2011;:217-220.

31. Nouri A, et al. Assessment of yield, yield related traits and drought tolerance of durum wheat genotypes (*Triticum turjidum* var. *durum* Desf.). Australian Journal of Crop Sci. 2011; 5:8-16.

32. Nouri-Ganbalani A, et al. Effects of drought stress condition on the yield and yield components of advanced wheat genotypes in Ardabil, Iran. J Food Agric Environ. 2009;7:228-234.

33. Obsa BT, et al. Genetic analysis of developmental and adaptive traits in three doubled haploid populations of barley (*Hordeum vulgare* L.) Springer-Verlag Berlin Heidelberg. 2016

34. Paolo ED and Rinaldi M. Yield response of corn irrigation and nitrogen fertilization in a Mediterranean environment. Field Crop Res. 2008; 105:202-210.

35. Plaut Z, et al. Transport of dry matter into developing wheat kernels. Field Crop Res. 2004; 96:185-198.

36. Reynolds MP, et al. Prospects for utilizing plant-adaptive mechanisms to improve wheat and other crops in drought and salinity-prone environments. Ann Appl Biol. 2005;146:239-259.

37. Richards RA, et al. Breeding opportunities for increasing the efficiency of water use and crop yield in temperate cereals. Crop Sci. 2002; 42:111-121.

38. Rosielle AA and Hamblin J. Theoretical aspects of selection for yield in stress and non-stress environments. Crop Sci. 1981;21:943-946.

39. Sharifi S, et al. Evaluation of drought tolerance and yield potential winter barley (*Hordeum vulgare* L.) genotypes. J Food Agric Environ. 2011;9:419-422.

40. Tadayyoun MR and Emam Y. Cultural management under drought stress. National Drought Seminar, Issues and Mitigation. 13-15 May, College of Agriculture, Shiraz University.2009;156-171.

41. Wajid A, et al. Influence of sowing date and irrigation levels on growth and grain yield of wheat. Pak J Agr Sci. 2002;39:22-24.

42. Yordanov I, et al. Plant responses to drought and stress tolerance. Bulgarian J Plant Physiol. Special Issue. 2003;187-206.