RESEARCH ARTICLE **(Open Access)**

Evaluation of drought resistance of barley (*Hordeum vulgare* L.) cultivars using agronomic characteristics and drought tolerance indices

MOHSEN SAEIDI[1], MAJID ABDOLI[2,3*], MANDANA AZHAND[4], MARYAM KHAS-AMIRI[4]

[1]Assistant Prof., Department of Agronomy and Plant Breeding, Campus of Agriculture and Natural Recourse, Razi University, Kermanshah, Iran.

[2]Ph.D. Student in Crop Physiology, Department of Agronomy and Plant Breeding, Faculty of Agriculture, Maragheh University, Maragheh, Iran.

[3]Young Researchers and Elite Club, Zanjan Branch, Islamic Azad University, Zanjan, Iran.

[4]Former M.Sc. Student in Agronomy, Department of Agronomy and Plant Breeding, Campus of Agriculture and Natural Recourse, Razi University, Kermanshah, Iran.

Abstract:

In order to determine the performance of barley under drought stress conditions and screening quantitative indices of drought tolerance, twelve barley (*Hordeum vulgare* L.) cultivars were tested in a split-plot arranged in a randomized complete blocks design with three replications under irrigated and post-anthesis water deficiency conditions. This study was carried out in the field research of campus of agriculture and natural resources, Razi university, Kermanshah state in the west of Iran during 2010-2011. The results showed that post anthesis water deficiency caused 22, 18.3, 5.9, 5.5 and 21.9 percent reduction in grain yield, biomass, thousand grain weight, number of grain per spike and number of spike per m^2 in average respectively, but had no significant effect on harvest index. Mean comparisons showed that Nosrat cultivar with 838 g m^{-2} and Afzal cultivar with 392 g m^{-2}, respectively had the highest and the lowest grain yield under non-stress condition. Under water stress environment Nosrat and Karoun cultivars with 696 and 656 g m^{-2} and also, Aras and Sahra cultivars with 322 and 327 g m^{-2}, respectively had the highest and the lowest grain yield. The estimates of stress tolerance attributes indicated that the identification of drought-tolerant genotypes based on a single criterion was contradictory. For example, according to STI, GMP and MP cultivars Nosrat, Karoun and Sararud were the most, whereas Aras and Afzal cultivars the least relative tolerant genotypes. As to YI cultivars Nosrat, Karoun and Sararud were the most and Aras, Sahra and Afzal the least relative tolerant genotypes. According to YSI, SSPI, RDI and ATI indices selected the Sararud and Zarjo cultivars as the most relatively tolerant genotypes. DI selected the cultivars Sararud, Nosrat and Karoun as the best, while the cultivars Sahra, Aras and Reihan as the the worst relatively tolerant genotypes. Grain yield in stress condition was significantly and positively correlated with MP, GMP, STI, Harm, YI and DI. Also, grain yield in non-stress condition was significantly and positively correlated with MP, GMP, STI, Harm, YI, DI and ATI indicating that these criteria were more effective in identifying high yielding cultivars under different moisture conditions.

Keywords: Barley, Water deficiency, Agronomic characteristics, Drought tolerance indices.

Abbreviations: Grain Yield (Y), Biomass (B), Harvest Index (HI), Thousand Grain Weight (TKW), Number of Grain per Spike (NGPS), Number of Spike per m^2 (NSPM), Potential Yield (Yp), Stress Yield (Ys), Stress Susceptibility Index (SSI), Stress Tolerance Index (STI), Geometric Mean Productivity (GMP), Tolerance (TOL), Mean Productivity (MP), Relative Drought Index (RDI), Yield Index (YI), Yield Stability Index (YSI), Drought Resistance Index (DI), Abiotic Tolerance Index (ATI) and Stress Susceptibility Percentage Index (SSPI).

1. Introduction

Barley (*Hordeum vulgare* L.) is grown as a commercial crop in one hundred countries and is one of the most important cereal crops in the world. Barley assumes the fourth position in total cereal production in the world after wheat, rice and maize [13]. Among all the factors limiting barley productivity, drought remains the single most important factor affecting the world security and sustainability in agricultural production.

Drought, the most important factor limiting considered for crops successful production in world wide. This problem, combined with physical and environmental factors that trigger stress in plants and reduce growth. Water stress caused by delay, weaken

Correspondence: Majid Abdoli, Department of Agronomy and Plant Breeding, Faculty of Agriculture, Maragheh University, Maragheh, Iran; Email: majid.abdoli64@yahoo.com;
(Accepted for publication 17 October 2013)
***ISSN**: 2218-2020, © Agricultural University of Tirana*

and/or lack of seedling establishment. Thus, conditions prepare for epidemic diseases, plant pests attack, physiological and biochemical changes. Even in cases of minor, injured and ultimately with reduction growth, damages yield [1]. So that, drought stress is the most significant environmental factor to impact on growth and yield of crops and it affects 40 to 60% of the world's agricultural lands [8].

To evaluate response of plant genotypes to drought stress, some selection indices has been proposed based on a mathematical relation between stress and optimum conditions [9, 17]. Drought indices which provide a measure of drought based on loss of yield under drought condition in comparison to normal condition have been used for screening drought tolerant genotypes [31]. These indices are either based on drought resistance or susceptibility of genotypes [17]. Drought resistance is defined by Hall [24] as the relative yield of genotype compared to other genotypes subjected to the same drought stress [24]. Drought susceptibility of a genotype is often measured as a function of the reduction in yield under drought stress [5].

Breeding for drought resistance is complicated by the lack of fast, reproducible screening techniques and the inability to routinely create defined and repeatable water stress conditions when a large amount of genotypes can be evaluated efficiently [41]. Achieving a genetic increase in yield under these environments has been recognized to be a difficult challenge for plant breeders while progress in grain yield has been much higher in favourable environments [42]. Thus, drought indices which provide a measure of drought based on yield loss under drought condition in comparison to normal condition have been used for screening drought-tolerant genotypes [31].

Rosielle and Hamblin [43] defined stress tolerance (TOL) as the differences in yield between the stress and non-stress environments and mean productivity (MP) as the average yield under stress and non-stress environments. Fischer and Maurer [18] proposed a stress susceptibility index (SSI) of the cultivars. Fernandez [17] defined a new advanced index (STI), which can be used to identify genotypes that produce high yield under both stress and non-stress conditions. Other yield based estimates of drought resistance are geometric mean (GM), MP and TOL. The Geometric mean is often used by breeders interested in relative performance since drought stress can vary in severity in field environment over years [41].

Fischer and Wood [19] introduced another index as relative drought index (RDI). Bidinger *et al.* [4] suggested drought response index (DRI) with its positive values indicating stress tolerance. Other yield based estimates of drought resistance are yield index (YI) [20] and yield stability index (YSI) [7].

Yield stability index (YSI) also was computed and suggested by Bouslama and Schapaugh [7]. This parameter is calculated for a given genotype using grain yield under stressed relative to its grain yield under non-stressed conditions. The genotypes with high YSI is expected to have high yield under stressed and low yield under non-stressed conditions [32]. In present study, drought tolerance in twelve genotypes of barley was investigated under post-anthesis drought stress conditions based on drought tolerance indices.

2. Materials and Methods

2.1. Plant material and treatments

This research carried out during 2010-2011 in the field research of campus of agriculture and natural resources, Razi university, Kermanshah state in the west of Iran (34º 20' N latitude, 47º 20' E longitude, elevation 1351 m above see level) in the moderate-cold and semi arid zone. he soil was a clay loam (36.1% clay, 30.7% silt) and the experiment was laid out in a split-plot arranged in a randomized complete blocks design with three replications. Two levels of moisture regimes (includes: irrigation in all stages of plant growth normally and post anthesis water deficiency with withholding of irrigation) as the main-plot and different improved cultivars (includes: Aras, Afzal, Jonub, Reihan, Zarjo, Sararud, Sahra, Fajr-30, Karoun, Gorgan-4, Makuei and Nosrat) as sub-plot were considered. Date of anthesis was determined from middle rows in each plot when 50% of the spikes had extruded anthers [12]. Seeds were sown at a density of 400 seeds m^{-2} on 12^{th} October. Humidity and moderate temperatures during the crop season is presented in Table 1.

2.2. Grain yield and some agronomic traits

Grain yield, biomass and number of spike per m^2 for each cultivar were measured by harvesting 1 m^2 of the central part of each plot at crop maturity. Harvest index was measured by dividing grain yield to biomass production. In order to measuring grain yield components such as: number of grain per spike and thousand grain weight, 10 plants randomly selected and measurements were performed.

Table 1. Minimum, maximum and mean of temperature and relative humidity also precipitation in the Kermanshah region in the west of Iran during 2010-2011.

Month	*Temperature (C°)*			*Precipitation (mm)*	*Relative Humidity (%)*		
	Min	**Max**	**Mean**		**Min**	**Max**	**Mean**
Oct.	10.6	30.3	20.4	1	13.2	46.4	29.8
Nov.	4.5	21.9	13.2	31	22.8	66.8	44.8
Dec.	-1.5	16.8	7.7	24	26.5	62.4	44.5
Jan.	-2.2	9.6	3.7	50	47.1	91.0	69.1
Feb.	-2.7	8.0	2.7	65	52.1	94.2	73.2
Mar.	0.6	15.4	8	21	28.1	82.0	55
Apr.	4.5	20.1	12.3	47	24.6	78.8	51.7
May.	9.5	23.6	16.5	128	33.6	87.4	60.5
Jun.	12.8	33.8	23.3	0	11.3	51.1	31.2
Jul.	17.1	38.5	27.8	0	6.6	32.1	19.4
Aug	18.1	39.5	28.8	0	6	27.7	16.9
Sep	13.8	34.6	24.2	0	7.8	32.0	19.9

Table 2. Drought tolerance indices.

Index	Formula	Reference
Stress Susceptibility Index Stress Index	$SSI = [1-(Ys/Yp)]/SI$ $SI = \left(1-\frac{\bar{Y}s}{\bar{Y}p}\right)$	Fischer and Maurer [18]
Stress Tolerance	$TOL = Yp - Ys$	Rosielle and Hamblin [43]
Mean Productivity	$MP = \frac{Ys+Yp}{2}$	Rosielle and Hamblin [43]
Geometric Mean Productivity	$GMP = \sqrt{Ys \times Yp}$	Fernandez [17]
Stress Tolerance Index	$STI = \frac{Yp}{\bar{Y}p} \times \frac{Ys}{\bar{Y}s} \times \frac{\bar{Y}s}{Yp} = \frac{Yp \times Ys}{(\bar{Y}p)^2}$	Fernandez [17]
Harmonic Mean	$HARM = \frac{2(Yp \times Ys)}{Yp + Ys}$	Kristin *et al.* [27]
Relative Drought Index	$RDI = \frac{(Ys \times Yp)}{(\bar{Y}s + \bar{Y}p)}$	Fischer and Wood [19]
Yield Index	$YI = \frac{Ys}{\bar{Y}p}$	Lin *et al.* [29]
Yield Stability Index	$YSI = \frac{Ys}{Yp}$	Bouslama and Schapaugh [7]
Drought Resistance Index	$DI = \frac{Ys \times (Yp \times Ys)}{(\bar{Y}s)}$	Lan [28]
Abiotic Tolerance Index	$ATI = \left[\frac{(Yp - Ys)}{(\bar{Y}p / \bar{Y}s)}\right] \times \sqrt{Yp \times Ys}$	Moosavi *et al.* [34]
Stress Susceptibility Percentage Index	$SSPI = \frac{(Yp - Ys)}{2(\bar{Y}p)} \times 100$	Moosavi *et al.* [34]

Yp and Ys: Grain yield of each genotype under non-stress and stress conditions, respectively.
Ỹp and Ỹs: Mean grain yield of all genotypes under non-stress and stress conditions, respectively.

2.3. Drought resistance indices

In order to estimates the sensitivity and tolerance indices in post anthesis water stress in different improved wheat cultivars, the relationships that proposed by Fischer and Maurer [18], Rosielle and Hamblin [43], Fernandez [17], Kristin *et al.* [27], Lin *et al.* [29], Lan [28], Moosavi *et al.* [34], Fischer and Wood [19] and Bouslama and Schapaugh [7] were used. These indices are includes (Table 2).

2.4. Statistical analysis

Statistical analyses were performed using MSTATC and SAS softwares. Mean comparisons were also performed using LSD at 5% level.

3. Result and Discussion

3.1. Effects of post-anthesis water deficiency on agronomic traits

The results obtained from mean comparison analysis of grain yield and its components are shown in Table 2. showed that post anthesis water deficiency stress caused 22, 18.3, 5.9, 5.5 and 21.9% reduction in grain yield, biomass, thousand grain weight, number of grain per spike and number of spike per m^2 in average respectively, but had no significant effect on harvest index. The averages of grain yield, biological weight (dry matter weight) and thousand grain weight of different cultivars in well watered condition were 613 g m^{-2}, 1660 g m^{-2} and 41.1 g respectively, while under water deficiency stress these values significantly reduced to 478 g m^{-2}, 1356 g m^{-2} and 38.7 g. Gupta *et al*. [22] evaluated two spring wheat cultivars, Kalyansona and C-306, for yield and yield attributes and noted that water stress caused significant reduction in plant height, leaf area, number of grain per spike, test weight and yield.

The results showed that there were significant differences among genotypes in respect to grain yield under non-stress condition. Also, significant differences were observed among genotypes under stress condition (Table 3). These results demonstrate high diversity among genotypes that enable us to select genotypes under non-stress and stress environments. Grain yield of main spike of wheat genotypes is significantly affected due to severe water stress. Mean comparisons showed that Nosrat cultivar with 838 g m^{-2} and Afzal cultivar with 392 g m^{-2}, respectively had the highest and the lowest grain yield under non-stress condition (Table 3). Under water stress environment Nosrat and Karoun cultivars with 696 and 656 g m^{-2} and also, Aras and Sahra cultivars with 322 and 327 g m^{-2}, respectively had the highest and the lowest grain yield. Blum and Pnuel [6] reported that the final grain yield and its associated traits of bread wheat were significantly decreased due to water stress. Reduction in grain weight of wheat was also reported by various other researchers [1, 2, 36]. Kar *et al*. [25] observed that under water deficit condition, supplemental irrigation during reproductive phases had a significant effect on increasing seed yield. Water stress at flowering negatively influenced the formation of grain, seed size, resulting in lower final grain yield.

At normal irrigation, comparison of means among all genotypes under study showed significan differences with each other. The highest (48.8 and 48 g) thousand grain weight was noted in Sararud and Gorgan-4 cultivars and lowest (36.3 g) was in Fajr-30 (Table 3). Post-anthesis water stress reduced thousand grain weight of all genotypes. In term of the thousand grain weight under water stress condition, Sararud cultivar had the highest (44.5 g) and Fajr-30 cultivar had the lowest values (33.7 g). The results of this conform to the findings of Karim *et al*. [26] and Baque *et al*. [3] who reporteds that water stress reduced grain yield by reducing productive tillers per plant, fertile spikelet per plant, number of grains per plant and individual grain weight.

Water stress at anthesis caused significant effect on yield traits and cultivars also showed significant variability for grain $spike^{-1}$, grain yield per plant, biological weight (dry matter weight) and harvest index. In term of the harvest index under well water condition, Nosrat and Fajr-30 cultivars had the highest (42.1%) and Afzal cultivar had the lowest values (25.3%). But, under post anthesis water deficiency stress Sararud and Fajr-30 cultivars had the highest (42.3 and 41.4%, respectively) and Aras cultivar lowest (27.7%) values (Table 3).

Mean comparisons showed that Karoun cultivar with 2230 g m^{-2} and also, Aras and Reihan cultivars (1350 and 1380 g m^{-2}), respectively had the highest and the lowest biological yield under well water condition (Table 3). Under water stress environment Karoun cultivar with 1880 g m^{-2} and Sahra cultivar with 1020 g m^{-2}, respectively had the highest and the lowest biological yields.

It can be seen from the data in Table 3. that significant differences were found among cultivars in terms of the number of grain per spike and number of spike per m^2. In term of the number of grain per spike under well water condition, Karoun and Makuei cultivars had the highest (45.8 and 43.2 grain $spike^{-1}$) and Sararud cultivar had the lowest values (18.9 grain $spike^{-1}$). Under post anthesis water deficiency stress Karoun and Makuei cultivars had the highest (41.5 and 41.4 grain $spike^{-1}$, respectively) and Sararud cultivar lowest (18.6 grain $spike^{-1}$) values (Table 3). Edward and Wright [11] in their studies also reported that the yield components like grain number and grain size were decreased under pre-anthesis drought stress treatment in wheat. Water stress at various stages specially before anthesis can reduce number of heads and number of kernels per ear [10, 23].