ORIGINAL ARTICLES

Evaluation of barley (*Hordeumvulgare* L.)Pure lines for drought tolerance

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ABSTRACT

In Ethiopia, drought is a major problem that causes high yield reduction in barley producer regions. Thus, search of drought tolerant barley genotypes is the first and most crucial nationwide issue to alleviate the problem sustainably. Hence the current study was carried out to evaluate and identify drought tolerant pure lines using 16 barley genotypes under greenhouse conditions using randomized complete block design with two irrigation regimes through computation of nine drought tolerance indices. The analysis of variance showed highly significant ($P<0.01$) differences for yield of drought stress, non-stress conditions and for all drought tolerance indices. Stress tolerance index, geometric mean productivity and mean productivity were the most powerful and effective predictors identified genotypes under stress and non-stress conditions. Cluster and principal component analyses were classified genotypes according to drought tolerance ability and yield stability. Most of them confirmed that 18294-01, 235243-01, 224751-01, 238367-01, 230205-01 and 230207-01 were found drought tolerant and yield stable pure lines under drought stress and non-stress environments, especially 18294-01 and 235243-01 were the superior ones fitted for most of criteria. Therefore barley pure lines identified as drought tolerant and yield stable can be recommended to be used in hybridization as parents for improvement of drought tolerant barley varieties in breeding program. However, further investigation and identification of desirable pure lines at field level by the aid of marker assisting selection canbe recommended to be taken into consideration.

Key words: Barley, Drought, Indices, Tolerance, Yield

INTRODUCTION

Barley (*Hordeumvulgare* L.) is an important malting, food, and feed crop and ranks fourth in global production among cereal crops next to corn, rice, and wheat (FAO, 2013). Barley is an important grain crop in Ethiopia and has diverse ecologies being grown from 1800 to 3400 m altitude in different seasons and production systems (Muluken, 2013). Between 2003/04 and 2013/14, the number of smallholders growing barley increased from 3.5 million to 4.5 million; yields increased from 1.17 metric tons per hectare to 1.87 metric tons per hectare; and total production grew from 1.0 million tons in 2005 to about 1.9 million tons in 2014 (CSA, 2005; CSA, 2014).

Currently barley is substantially grown for animal feed, malt products and human food respectively. Traditionally, barley is very important food crop in the semi-arid regions of Africa and Asian counties including Ethiopia. In Ethiopia barley is mainly used in making of many traditional foods, beverages and its straw is used for animal feed, construction and bedding (Bekele*et al*., 2005).

Drought stress is an adverse environmental condition that can seriously reduce crop productivity and the effect depends on its intensity and duration. In Ethiopia, rainfall variability and associated droughts among abiotic stresses are the major causes of food shortages and famines. Drought problem is caused not only by shortage of rainfall but also it can be appeared by its erratic shower in both agro-ecology zones. Before the 1980s, drought was most protracted in the northern and eastern regions of Ethiopia. However, the number of drought-affected areas has dramatically increased and now includes the most productive regions in the west and south (Yaynu, 2011).There were previous drought base studies, which were carried out in different times and environments by Al-Abdallat*et al*., (2017), Vaezi*et al*., (2010), Ashraf *et al*., (2015) and Samarah and Alqudah (2011) using different irrigation regimes and identified promising stable and drought tolerant genotypes.

In Ethiopia different drought base studies were conducted to alleviate drought problem, viz. identification of 14 drought tolerance accessions from the existing landraces (Yaynu, 2011), two accessions were found stable and drought tolerant by Kiflu (2009) at Enadayesus of Tigray National Regional State(NRS) using 175 landraces, Yosef*et al*.,(2011) at Sirinka Agricultural Research Center (SARC) were proposed three accessions for released varieties and Sintayehu and Tesfahun (2011) identified four genotypes as stable and drought tolerant among the 16 genotypes at Dera of Oromia NRS using landraces and released varieties to be used as a check. However, in Ethiopian context there is little information regarding drought tolerance aspects of the barley landraces considered in this study.

Parts of major barley producer regions especially *Belg* producers of Ethiopia (covers about 40% of the area and gives 46% of the total cereal production) are under drought stress conditions (CSA, 1992), and they are in need of drought tolerant varieties to be benefited from this short-term season, and as well as in the main crop season which have erratic and short period of rain fall under different agro-ecologies. The current study was conducted under greenhouse condition using landraces, in two irrigation regimes through computation of nine drought tolerance indices namely, drought tolerance index (TOL) and mean productivity (MP) (Rosielle and Hamblin 1981), stress susceptibility index (SSI) (Fischer and Maurer 1978), geometric mean productivity (GMP) and stress tolerance index (STI)(Fernandez 1992), stress tolerance (ST) (Fereres et al 1986), yield reduction ratio (YR) (Golestani–Araghi and Assad 1998), relative performance (P) (Abo-Elwafa and Bakheit 1999), yield index (YI) (Gavuzzi et al 1997) and yield stability index (YSI) Bouslama and Schapaugh (1984) were employed.

The main objectives of this study were to (1) evaluate the influence of drought stress on grain yield of barley genotypes, (2) identify drought tolerant barley genotypes based on drought tolerance indices and (3) study interrelationships among the screening methods like drought indices, correlation of indices, cluster and principal component analyses.

MATERIALS AND METHODS

Description of the study area

Pot experiment was carried out in a greenhouse conditions by creating controlled moisture stress environment at Holeta Agricultural Research Center (HARC), which has a mean temperature ranges from 22^{0}C to 6^{0}C.Plastic pots used in the greenhouse were 25 cm in diameter and 22.5 cm deep, filled with 6 kg air-dried soil with a mixture of soil, peat and sand in ratio of 3:2:1 (in volume/ volume).The soil moisture of each experimental pot (non-stress and drought-stress) was maintained with the required amounts of water by weighing irrigated (daily) pots with together watering plants (Ozturk et al. 2002). Thus the weight of soil moisture at Field Capacity (FC) was calculated as the difference between the soil weight after 3 days drainage (from saturated) and soil weight after oven drying for 104 °C for 24 h. Based on these measurements weights of pots, pots with air dry soil, oven dry, and pots with irrigated soil at field capacity were fixed Ozturk*et al*., 2002, Samarah and Alqudah, 2011). Sowing was carried out in November 31st, 2016 by direct drilling the seeds in each experimental pot.

Experimental materials

In this study a total of 16 selected barley genotypes were used, selected from the preliminary screening of field experiment conducted at Mekele Agricultural Research Center (MARC), and out of these the one was released variety (Gobie) used as standard check obtained from Holeta Agricultural Research Center (HARC), while the rest 15 were pure lines purified and screened under field condition during 2014 main cropping season at HARC and in 2015 using on farm irrigable land before the field experiment was taken place in three different moisture stress environments (HARC, Geregera of SARC and MARC) (Table 1). 230 accessions were used as a source, obtained from Institute of Bio-diversity Conservation Research for Ethiopia (IBCRE).

Table 1. Barley genotypes used in greenhouse experiment for drought tolerance

Genotype	Source	Pure line/Var.	Status	Row No.
238367	IBCRE	238367-01	Pure line	2R
234353	IBCRE	234353-01	Pure line	2R
234296	IBCRE	234296-02	Pure line	2RLF
230224	IBCRE	230224-01	Pure line	2R
242579	IBCRE	242579-01	Pure line	2R
18294	IBCRE	18294-01	Pure line	2R
230192	IBCRE	230192-01	Pure line	2R
231340	IBCRE	231340-01	Pure line	2R
235243	IBCRE	235243-01	Pure line	2R
230206	IBCRE	230206-01	Pure line	2R
224751	IBCRE	224751-02	Pure line	2R
17187	IBCRE	17187-01	Pure line	2R
230205	IBCRE	230205-01	Pure line	2R
230207	IBCRE	230207-01	Pure line	2R
230172	IBCRE	230172-02	Pure line	2R
Gobie	HARC	Gobie	Variety	2R

2R- Two - row, 2RLF – two- row with lateral floret

Experimental design and procedure

A pot experiment was conducted in randomized complete block design (RCBD) with two irrigation regimes (non-stress and drought-stress) by accommodated three replications (23 pots/ replication). Hence each set (irrigation regime) was comprised 69 pots. Sowing was carried out by direct drilling the seeds in each experimental pot. Nine seeds per pot and 27 seeds per genotype in one set of treatment were grown.

Drought stress application and procedures

To carry out stress application four major soil water content characteristics were determined, viz. field (container) capacity, oven dry, available water content and permanent wilting point. Hence FC at 95% (non-stress) and 45% (drought stress) were calculated from the soil mass of after drainage (for 3 days) of saturated soil and the soil mass of oven dry which was taken before in the laboratory. So watering of each pot was carried out based on its FC fixed after drainage that is to determine the daily loss of water through evapo-transpiration. Drought stress application was conducted in vegetative and reproductive growth stages.

The first drought stress

For the first four weeks, from date until six-leaf stage (end of seedling growth) all pots of treatments (non-stress and drought stress treatments) were irrigated at 95% of field capacity (FC). At six-leaf stage (Zadoks,16) the first relative water content (RWC) samples were taken for different RWC measurements in the laboratory, and then followed by withholding of water for a period of 9-14 days. Withholding of water on drought stress treatments was continued up to the setting of permanent wilting point (PWP) for each studied barley genotype in different periods of time. This was the first drought stress taken place at vegetative growth stage (Ozturk*et al*. 2002).

The second drought stress

Then after first drought stress was ended, re-irrigation of plants were continued (maintained at 95% of field capacity) until heading growth stage was set (Zadoks, 55). Until the second drought stress was taken place, the two treatments were irrigated with equal amount of water content (95% FC). At the beginning of the heading growth stage two treatments were imposed in two different irrigation regimes, viz., 95% field capacity (non-stress), and 45% field capacity (drought stress). Stressed treatments were started to impose at 50% heading growth stage (emergence of inflorescence) (Zadoks, 55) and continued until kernels dough growth stage (Zadoks,87) was set. All irrigation regimes (non-stress and drought stress) were applied by weighing pots daily, and maintaining them at fixed soil moisture content (Ozturk*et al*. 2002).

Data collection

Yield data were collected on yield and yield related traits in the greenhouse after harvesting, and then threshing was taken place. Data were collected on 5 randomly plants from the pots based on barely descriptor.

Data analysis

Grain yield per plant under non-stress (Yp), and drought stress conditions (Ys) and nine drought tolerant indices were calculated. Moreover, Pearson correlation coefficients were computed for each pair of the possible pair-wise comparisons of the drought tolerance indices. Differences between means were compared using Least Significant Difference (LSD) at 5% level of probability. Cluster analysis of diagram and principal component analyses were done by using) SAS 9.3 (SAS institute 2011). Estimation of drought tolerance indices was done as shown below.

Table2. Stress tolerance indices used for the evaluation of barley genotypes to drought tolerance

S.No.	Stress tolerance indices	Equation1	Reference
1	Stress susceptibility index(SSI)	SSI = 1-(Ys/Yp)/SI	Fisher and Maurer (1978)
2	Yield reduction ratio (YR)	YR = 1-(Ys/Yp)	Golestani-Araghi and Assad, (1998)
3	Mean productivity (MP)	MP = (Ys+Yp)/2	Rosielle and Hambline (1981)
4	Stress tolerance (TOL)	TOL = Yp-Ys	Hossain et al., (1990)
5	Geometric mean productivity (GMP)	GMP = (Yp*Ys)½	Fernandez (1992)
6	Stress tolerance index (STI)	STI = (Yp*Ys)/(∏p)²	Fernandez, (1992).
7	Yield index (YI)	YI = Ys / ∏s	Gavuzzi et al. (1997)
8	Yield stability Index (YSI)	YSI = Ys/Yp	Bouslama and Schapaugh (1984)
9	Relative performance (P)	P = (Ys/Yp)/∏s/∏p	Abo-Elwafa and Bakheit (1999)

Ys and Yp, are grain yield of each genotype under stress and non-stress conditions, respectively. While Ŷs and Ŷp are the mean grain yield of all genotypes in stress and non-stress conditions respectively

RESULTS AND DISCUSSION

Analysis of variance

The analysis of variance showed highly significant ($P<0.01$) differences for yield of non-stress and drought stress irrigation regimes (Yp and Ys) and for all drought tolerance indices.(Table 3). Similar results were reported on barley genotypes showed high significant differences for all criteria (Nazari and Pakniyat, 2010 andSharafi*et al.*, 2014).

Table 3. Analysis of variance of Yp, Ys and stress tolerance indices of 16 barley genotypes (Mean squares) under greenhouse condition

SOV	DF	Yp	Ys	STI	TOL	MP	GMP	SSI	YR	P	YI	YSI
BLK	2	0.38	0.09	0.02	0.53	0.01	0.08	0.08	0.03	0.19	0.10	0.03
TRT	15	0.84**	0.12**	0.06**	0.76**	0.29**	0.20**	0.08**	0.03**	0.20**	0.14**	0.03**
Error	30	0.05	0.01	0.00	0.08	0.01	0.01	0.01	0.00	0.03	0.02	0.00
CV		9.24	11.88	14.65	18.97	6.84	6.77	12.20	12.11	16.26	11.89	16.17
Mean		2.44	0.99	0.44	1.44	1.72	1.55	0.93	0.57	1.10	1.09	0.43

**=significance at 1%, Yp= yield potential under non-stress condition, Ys= yield under drought stress condition, STI= stress tolerance index, TOL= stress tolerance, MP=mean productivity, GMP=geometric mean productivity, SSI=stress susceptibility index, YR=yield reduction ratio, P=relative performance, YI=yield index, YSI=yield stability index

Mean yield performances

Mean yield performance of Yp (yield potential),Ys (yield under stress) and tolerance indices are given in table 4.The highest grain yield per plant under non-stress condition was obtained from 230206-01, Gobie and 231340-01 followed by 234353-01, 234296-02, 18294-01 and 235243-01.Meanwhile under non-stress condition the lowest grain yield was observed on pure line 17187-01 followed by 230224-01 and 242579-01..On the other hand under drought stress condition pure line 18294-01 showed high grain yield followed by 235243-01 and 224751-02. Under similar stress condition genotype pure line 231340-01 was showed the lowest grain yield per plant (Table 4).

Mean performance under the two stress levels indicated that 18294-01 and 235243-01 were showed the highest yield under both conditions, whereas 17187-01 was found with the lowest yield under both conditions. 234296-02, Gobie, 234353-01 231340-01 and 230206-01 were highly reduced the grain yield under drought stress condition; on the other hand 224751-02 was well performed only under drought stress condition. Generally results showed that grain yield per plant were reduced under drought stress condition due to drought stress effect at vegetative and reproductive stages. Mean grain yield under stress (Ys) condition was 1.00 g plant^{-1}which was showed a reduction of 59.25% as compared to under non-stress (Yp) condition. Similar results were reported by Subhani *et al*., (2015), Sharafi *et al*., (2014).

Drought tolerance indices

A smaller value of drought tolerance index (TOL)is favored to select drought tolerant genotypes. Hence 17187-01 and 230224-01 were showed the lowest TOL followed by 230207-01 (Table 4). The lower this index is the more genotypes are drought resistance (Sio-Se Mardeh *et al*., 2006). On the other hand 231340-01 and Gobie were showed maximum values of TOL followed by 234296-02, 230206-01 and 234353-01,, indicated that genotypes with high TOL were drought sensitive genotypes.AS defined by Rosielle and Hamblin (1981) a larger of TOL value represents relatively more sensitivity to stress, and exhibited high grain yield per plant under non-stress condition, but low under drought stress condition. Similar results were reported by (Ashraf *et al*., 2015, Subhani*et al*., 2015).But in these study pure lines with low TOL was found low in grain yield under both conditions, and here TOL was not a good indicator index. Similar results were reported by Subhani *et al*., (2015) On the other hand indicated the fact that genotypes with high grain yield under non-stress were showed high TOL like Gobie, 231340-01 and 230206-01 (Table 4).

As far as stress susceptibility index (SSI) was concerned, 10 genotypes were showed lower values of SSI less than 1 (Table 4). But 230224-01, 18294-01, 224751-02 and 230207-01 were found with the least values of SSI. So values of SSI lower than 1 denotes low drought susceptibility and values higher than 1 indicate high drought susceptibility. Whereas genotypes like 234296-02, 231340-01 and Gobie were exhibited high values of SSI followed by 234353-01 and 230206-01,which were showed the highest grain yield reduction under drought stress (Ys) condition.Similar results were provided by Khalili*et al*., (2016) and JalilAjalli and Salehi (2012).

Genotypes with high values of stress tolerance index (STI), geometric mean productivity (GMP) and mean productivity (MP) can be selected as tolerant genotypes to drought stress conditions (Ashraf *et al*., 2015). Thus, 18294-01 was showed the highest values of STI, GMP and MP followed by 235243-01 and 230206-01(Table 4), but 18294-01 showed the highest value for STI, MP, GMP and Ys, followed by 235243-01 which indicated that the two pure lines were drought tolerant and high yielder, that can be selected for drought stress and non-stress environments (Table 4).

Table 4. Mean values of Yp, Ys and stress tolerance indices of 16 barley genotypes under greenhouse condition

Genotype	Yp	Ys	STI	TOL	MP	GMP	SSI	YR	P	YI	YSI
238367-01	2.47^{d}	1.11^{bcde}	0.50^{cd}	1.36^{defg}	1.80^{cde}	1.66^{c}	0.90^{cd}	0.55^{bc}	1.16^{bc}	1.22^{bcde}	0.45^{bc}
234353-01	2.80^{ab}	0.95^{defg}	0.48^{cd}	1.85^{abc}	1.88^{bcde}	1.63^{cde}	1.07^{ab}	0.66^{ab}	0.88^{cde}	1.04^{defg}	0.34^{cd}
234296-02	2.88^{ab}	0.92^{efgh}	0.47^{cd}	1.96^{ab}	1.90^{bcd}	1.62^{cde}	1.11^{a}	0.68^{a}	0.83^{e}	1.00^{efgh}	0.32^{d}
230224-01	1.74^{g}	0.83^{fgh}	0.26^{fg}	0.90^{gh}	1.29^{f}	1.20^{g}	0.84^{de}	0.52^{cd}	1.25^{ab}	0.91^{fgh}	0.48^{ab}
242579-01	1.82^{g}	0.80^{fgh}	0.26^{fg}	1.02^{fg}	1.31^{f}	1.21^{g}	0.92^{bcd}	0.56^{bc}	1.13^{bcd}	0.87^{fgh}	0.44^{bc}
18294-01	2.87^{ab}	1.39^{a}	0.71^{a}	1.48^{cde}	2.13^{a}	1.99^{a}	0.83^{de}	0.51^{cd}	1.26^{ab}	1.52^{a}	0.49^{ab}
230192-01	2.51^{b}	0.87^{fgh}	0.39^{de}	1.64^{bcd}	1.69^{e}	1.47^{ef}	1.07^{abc}	0.66^{ab}	0.89^{cde}	0.94^{fgh}	0.34^{cd}
231340-01	2.96^{a}	0.75^{h}	0.40^{de}	2.22^{a}	1.86^{bcde}	1.48^{def}	1.21^{a}	0.74^{a}	0.66^{e}	0.81^{h}	0.26^{d}
235243-01	2.78^{ab}	1.30^{ab}	0.65^{ab}	1.48^{cdef}	2.04^{ab}	1.90^{ab}	0.87^{d}	0.53^{c}	1.20^{b}	1.42^{ab}	0.47^{b}
230206-01	3.09^{a}	1.00^{cdef}	0.55^{bc}	2.09^{ab}	2.04^{ab}	1.75^{bc}	1.10^{ab}	0.68^{a}	0.84^{de}	1.09^{cdef}	0.32^{d}
224751-02	2.35^{de}	1.20^{ab}	0.51^{c}	1.14^{efg}	1.78^{de}	1.68^{c}	0.79^{de}	0.49^{cd}	1.32^{ab}	1.31^{ab}	0.51^{ab}
17187-01	1.28^{h}	0.76^{gh}	0.18^{g}	0.52^{h}	1.02^{g}	0.99^{h}	0.67^{e}	0.40^{d}	1.52^{a}	0.83^{gh}	0.60^{a}
230205-01	2.29^{de}	1.14^{bcd}	0.46^{cd}	1.15^{efg}	1.71^{de}	1.61^{cde}	0.80^{de}	0.49^{cd}	1.31^{ab}	1.24^{bcd}	0.51^{ab}
230207-01	2.19^{de}	1.18^{bc}	0.46^{cd}	1.01^{g}	1.69^{e}	1.60^{cde}	0.74^{de}	0.45^{cd}	1.40^{ab}	1.29^{bc}	0.55^{ab}
230172-02	2.01^{ge}	0.90^{fgh}	0.32^{ef}	1.11^{efg}	1.45^{f}	1.33^{fg}	0.87^{d}	0.53^{c}	1.20^{b}	0.98^{fgh}	0.47^{b}
Gobie	3.06^{a}	0.89^{fgh}	0.49^{cd}	2.17^{a}	1.98^{ab}	1.65^{cd}	1.15^{a}	0.70^{a}	0.76^{e}	0.97^{fgh}	0.30^{d}

Yp,Ys= Grain yield under non-stress and stress condition respectively, STI= stress tolerance index, TOL= stress tolerance, MP= mean productivity, GMP= geometric mean productivity, SSI= stress susceptibility index, YR= yield reduction ratio, P= relative performance, YI= yield index, YSI= yield stability index

On the other hand 17187-01was showed the least values of STI, GMP and MP with high reduction of grain yield under drought stress (Ys) condition followed by 230224-01 and 242579-01. Similar results were reported by Khalili *et al.*, (2016).

Genotypes, such as 17187-01 was showed low value of yield reduction ratio (YR) followed by 230224-01, 18294-01, 224751-02, 230205-01 and 230207-01 (Table4), indicated that they were found with high grain yield under drought stress condition. On the other hand genotypes like 231340-01, Gobie, 234296-02 and 230206-01 were showed high values of YR, showed that yield reduction under drought stress condition was situated, because of their drought susceptibility and less yield stability. Similar results were provided by Saad*et al.*, (2014).

As far as relative performance (P) and yield index (YI) were concerned, genotypes such as 18294-01 and 224751-02 were showed high values followed by 230207-01 and 235243-01,showedthat they were found drought tolerant and yield stable genotypes. On the other hand genotype like 231340-01 was showed low value of P and YI followed by Gobie,, characterized as drought sensitive and as well as poor yield performance under stress condition. Similar results were reported by Saad*et al.*, (2014).

Genotype 17187-01 was showed high value of yield stability index(YSI) followed by 230224-01, 18294-01, 224751-02, 230205-01 and 230207-01(Table 4).So genotypes with high YSI were expected to have high grain yield in drought stress environment and perform poorly under non-stress environments (Ashraf*et al.*, 2015).The index indicated perfectly the two genotypes, that they performed high grain yield under drought stress condition were 18294-01 and 224751-02). Under similar condition Similar result was provided by Ashraf *et al.*, (2015), Subhani*et al.*, (2015). genotypes like 231340-01, Gobie and 234296-02 were showed the low value of YSI, indicated that genotypes were found with low grain yield under drought stress condition and high drought sensitive (Table 4).Similar results were reported by Khalili*et al.*, (2016).As far as pure line 17187-01 was concerned, YR and YS were not a good predictor according to its yield stability and drought tolerance character, but the opposite was observed.

Correlation analysis

Pearson correlation analysis between grain yield and drought tolerance indices, and within different drought tolerance indices can be used as criterion to estimate the most desirable genotypes for drought stress environments. Pearson correlation coefficient between drought tolerance indices and mean yield under stress and non-stress conditions presented Table 5.

According to the correlation matrix, grain yield under drought stress (Ys) condition showed positive correlation with grain yield under non-stress (Yp) condition (r = 0. 31), showed that high potential yield under optimum conditions can be applied in improved yield under stress condition will be low. Highly significant and positive correlation was found between grain yield under stress (Ys) and non-stress (Yp) conditions with STI (r=0.83, r=0.78), MP (r=0.58, r=0.95), GMP(r=0.80, r=0.81) and YI (r=1.0, r=0.31-ns) respectively, indicated that drought tolerant genotypes with high grain yield under stress and non-stress conditions were discriminated well by existed selected criteria (Table 5). The indices GMP, MP and STI were very similar to the selection based on Yp and Ys, they exhibited strong correlation with grain yield under both conditions ((except MP with Ys, r=0.58).

Table 5. Correlation coefficients between yield of non-stress (Yp), stress (Ys) and drought stress tolerance indices for 16 barley genotypes

Variabl	Yp	Ys	STI	TOL	MP	GMP	SSI	YR	P	YI	YSI
Ys	0.31^{ns}										
STI	0.78**	0.83***									
TOL	0.93***	-0.07^{ns}	0.49^{ns}								
MP	0.95***	0.58*	0.93***	0.77**							
GMP	0.81***	0.80**	0.99***	0.54*	0.95***						
SSI	0.74**	-0.39^{ns}	0.17^{ns}	0.93***	0.51*	0.23^{ns}					
YR	0.74**	-0.39^{ns}	0.17^{ns}	0.93***	0.51*	0.23^{ns}	1.00***				
P	-0.74**	0.39^{ns}	-0.17^{ns}	-0.93***	-0.51*	-0.23^{ns}	-1.00***	-1.00***			
YI	0.31^{ns}	1.00***	0.83**	-0.07^{ns}	0.58*	0.80**	-0.39^{ns}	-0.39^{ns}	0.39^{ns}		
YSI	-0.74**	0.39^{ns}	-0.17^{ns}	-0.93***	-0.51*	-0.23^{ns}	-1.00***	-1.00***	1.00***	0.39^{ns}	

ns, * ** and *** : Non-significant and significant at 5% , 1%, 0.1% probability levels , respectively. YP -Yield under non-stress condition, YS - Yield under water stress condition, STI - Stress tolerance index, TOL - Tolerance index, MP - Mean productivity, GMP - Geometric Average productivity, SSI - Stress susceptibility index, YR - Yield reduction ratio, YI - Yield index, YSI - Yield stability index

Grain yield under stress (Ys) and non-stress (Yp) conditions were showed non-significant negative and highly significant positive correlations with TOL (r=-0.07 r=0.93) respectively. It indicated that TOL can be taken as desirable criteria, since it has a low value with Ys.

Correlations among STI, MP, GMP and YI were showed similarly highly significant positive correlation, so they were identified as the most desirable predictor and appropriate indices for screening drought tolerance genotypes (Table 5).Similar results were reported by Ashraf *et al.*, (2015) and Khalili *et al.* (2012). STI was calculated based on GMP and thus rank correlation between STI and GMP was almost equal to 1.Its correlation with grain yield under stress (Ys) condition was better than grain yield under non-stress (Yp) condition (r=0.83 and r = 0.78, respectively) (Table 5).Hence STI was found more desirable and powerful index for drought tolerance. The current study results were coincided with (Nazari and Pakniyat, (2010).

YI was showed positive and non-significant correlation with YSI and P (r=0.37).They all have similar selection direction to identify drought tolerant genotypes, and due to that they showed similar correlation between them (Table 5). But except YI, the rests were not showed significant and positive correlation with Ys and Yp (r=0.39 and r=-0.74 respectively). So they were failed to use them as desirable and effective drought tolerance indices.YSI was showed highly significant and perfectly negative correlation with SSI and TOL (r= -0.93 and r= -1) respectively. Thus, a high value of this index is desirable and selection for this parameter (YSI) would also tend to favour low yielding genotypes. They can be used interchangeably depending on the direction of selection that a breeder demands to follow.

TOL was showed highly significant positive correlation with SSI (r=0.93).Thus, these indices can be considered as to reflect the similar information, which means that less drought susceptible genotypes were comprised the low value of TOL and SSI.SSI was showed perfectly positive correlation with YR (r=1.0). They all have similar selection direction, that the highest values of these indices the highest drought susceptibility and vice versa. Both SSI and YR were showed non-significant negative correlation (r=-0.37) and highly significant positive correlation (r=0.74) in similar direction with Ys and with Yp respectively (Table 5). Thus, these indices were not useful for discriminating genotypes under stress and non-stress conditions. Similar result was provided by Jalil Ajalli and Salehi (2012).SSI was depicted perfectly negative correlation with P (r=-1.0) and YSI (r=-1.0) and as well as non-significant negative correlation with YI (r=-0.39). High values of P, YSI and YI are indicators of drought tolerance, whereas SSI is an indicator of the opposite ones. YR was showed perfectively negative correlation with P (r=-1.0), YSI (r=-1.0) and non-significant negative correlation with YI (r=-0.39), indicated that YR has an opposite selection direction with P, YSI and YI.

Cluster analysis

Cluster analysis was performed based on squared Euclidean distance to classify the genotypes on the basis of drought tolerance indices and grain yield under drought stress and non-stress conditions(Ttable 6, and Fig. 1).Cluster analysis was showed that the most accepted groups of clusters were three (,cluster 1, 2, and 3).

Cluster-1: Under this cluster 6 genotypes were comprised, such as 238367-01, 224751-02, 230205-01, 230207-01, 18294-01 and 235243-01, which were found with moderate to high value of STI, MP, GMP and YI. In general genotypes under this cluster were found yield stable and drought tolerant under both conditions, but 18294-01 and 235243-01 were found the superior ones as the most desirable genotypes for both stress and non-stress environments. Under Cluster-2 also, 6 genotypes were included like 234353-01, 234296-02, 230206-01, Gobie, 230192-01 and 231340-01, which were performed moderate to high grain yield under non-stress condition, but low grain yield under drought stress condition. They were found drought sensitive groups. Almost all genotypes were showed low STI, MP, GMP, YI and YSI but with moderate to high TOL, SSI and YR. Under Cluster 3, four genotypes were included like230224-01, 242579-01, 230172-02 and 17187-01 which were found drought susceptible and low yielder under both (Ys and Yp) conditions. Similar results were provided by Samah Mariey and Rania Khedr (2017).

Table 6. Number of clusters and included accessions under each cluster for 16 genotypes

Cluster	Number	Genotypes/Treatments
1	6 (37.5%)	238367-01, 224751-02, 230205-01, 230207-01, 18294-01, 235243-01
2	6 (37.5%)	234353-01, 234296-02, 230206-01, Gobie, 230192-01, 231340-01
3	4 (25%)	230224-01, 242579-01, 230172-02, 17187-01

TRT: 1-238367-01, **2**-234353-01, **3**-234296-02, **4**-230224-01,

5-242579-01, **6**-18294-01, **7**-230192-01, **8**-231340-01

9-235243-01, **10**-230206-01, **11**-224751-02, **12**-17187-01

13-230205-01, **14**-230207-01, **15**-230172-02, **16**-GObie (No. of TRT=No of Genotypes displayed on dendrogeram below)

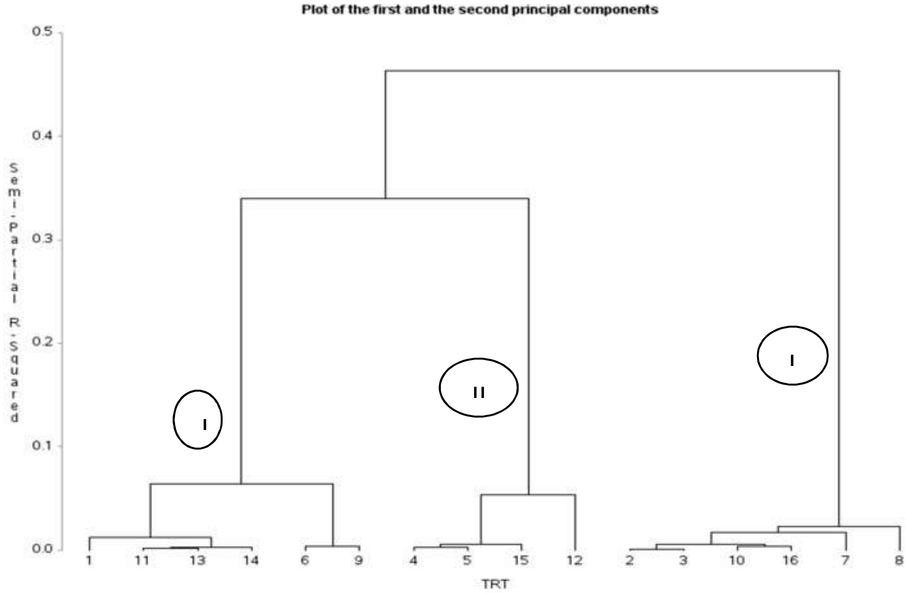

Figure.1. Dendrogeram of Ward's hierarchical clustering of 16 barley genotypes ranks based on drought resistance indices and yield of stress and non-stress conditions

Principal component analysis (PCA)

Principal component analysis of the first principal component (PC1) and second principal component (PC2), which were contained about 99.58% of the total variation (Table 9). The first principal component analysis (PC1) explained 59.73% of the variation with high positive values for Yp, STI, MP, GMP, TOL, SSI and YR, but Ys and YI with least positive values, and negative values with P and YSI as shown in Table 7. Therefore, the first principal component was described as stress sensitive component, which could discriminate the tolerant genotypes from sensitive ones. Genotypes under this component like 231340-01, Gobie, 230206-01, 234296-02, 234353-01 and 230192-01 were showed high grain yield under non-stress condition, but low under drought stress condition. In general genotypes were found drought sensitive ones with high TOL and SSI (Table 9, Fig.1) with compared to PC2.

The second principal component (PC2) explained 39.85 % of the total variability which was positively correlated with Yp, Ys, STI, MP, GMP, P, YI and YSI, and negatively correlated with YR, SSI and TOL as shown in Table 7. So the genotype with high and positive value of this component showed high yielding in non-stress and drought stress conditions as shown on table 9. Gentypes like 18294-01, 235243-01, 238367-01, 224751-02, 230205-01 and 230207-01 were exhibited yield stable and low drought susceptible under both conditions with highly correlation of Ys, STI, MP, GMP and YI, but with low TOL and SSI. Therefore the PC2 can be named as the yield stable and drought tolerance component.Similar results were provided by Samah Mariey and Rania Khedr (2017).

Table 7. Principal component analysis for Yp, Ys and stress tolerance indices of 16 barley genotypes

Variable	Prin1	Prin2	Prin3	Prin4	Prin5
Yp	0.38	0.11	0.37	0.21	-0.11
Ys	0.03	0.47	-0.33	0.23	-0.25
STI	0.24	0.37	0.08	-0.87	-0.18
TOL	0.38	-0.07	0.52	0.13	-0.02
MP	0.33	0.24	0.21	0.26	-0.20
GMP	0.26	0.36	-0.08	0.03	0.87
SSI	0.34	-0.23	-0.26	-0.04	0.04
YR	0.34	-0.23	-0.30	-0.03	0.03
P	-0.34	0.23	0.26	-0.02	0.23
YI	0.03	0.47	-0.33	0.23	-0.20
YSI	-0.34	0.23	0.30	0.03	-0.03
Eigenvalue	6.57	4.38	0.04	0.01	0.00
Variance%	59.73	39.85	0.00	0.00	0.00
Cumulative	59.73	99.58	100.00	100.00	100.00

Table 8. PCA communalities grain yields (Ys and Yp) and drought indices

Final Communality Estimates: Total = 10.954										
Yp	Ys	STI	TOL	MP	GMP	SSI	YR	P	YI	YSI
0.994	0.995	0.994	0.990	0.998	0.999	0.997	0.996	0.997	0.996	0.996

As on table 8 was shown the principal component analysis(PCA) outputs were found under similar communalities for grain yields under both conditions and drought indices. In PCA, all the variables were given all most the same weightage during the extraction process (Table 8).

Table 9. Values of Principal components for 16 barley genotypes

Genotype	Prin1	Prin2	Prin3	Prin4	Prin5
17187-01	-5.65	-1.76	0.45	-0.12	0.00
230224-01	-2.88	-1.69	-0.16	-0.01	-0.01
242579-01	-2.07	-2.18	-0.36	-0.08	0.00
230207-01	-2.01	2.03	0.07	0.17	-0.01
230172-02	-1.89	-0.98	-0.04	0.06	0.00
230205-01	-1.33	1.54	0.02	0.14	0.02
224751-02	-1.10	2.17	-0.06	0.07	0.01
238367-01	-0.02	1.12	-0.15	0.00	0.02
235243.01	0.87	3.15	-0.07	-0.11	-0.01
18294-01	0.93	4.18	0.07	-0.12	-0.03
230192-01	1.10	-1.69	-0.28	-0.03	0.00
234353-01	2.02	-0.64	-0.04	-0.01	0.02
234296-02	2.48	-1.02	0.01	0.01	0.01
230206-01	3.11	-0.09	0.17	-0.06	0.04
Gobie	3.21	-1.25	0.22	0.02	0.01
231340-01	3.22	-2.88	0.15	0.07	-0.06

prin: principal component, Yp and Ys: yield under non-stress and stress respectively, TOL: tolerance index, MP: mean productivity, GMP: geometric mean productivity, SSI: stress susceptibility index, YR: yield reduction ratio, P: relative performance, YI: Yield index, YSI: yield stability index

The selection of genotypes with high PC1 and PC2 can be more suitable for non-stress (Yp) and drought stress (Ys) of 16 barley genotypes under both conditions. Therefore, the 18294-01 and 235243-01 with high PC1 and PC2 can be more suitable pure lines for drought stress and non-stress conditions (Table 9, Fig. 1) and genotypes like 17187-01, 230224-01, 242579 and 230172-02 with low PC1 and PC2 were identified as highly drought stress susceptible genotypes with low yield stability. These results are in agreement with the findings of Samah Mariey and Rania Khedr (2017), Jalil Ajalli & Salehi (2013) and Sharafi *et al.* (2013).

CONCLUSION AND RECOMMENDATION

Analysis of variance, mean yield performance and drought tolerance indices were performed to estimate the yield stability and drought [illegible]e ability of barley pure lines. Com[illegible] of values of indices with correlation coefficient was used to determine the most effective and powerful indices to identify desirable genotypes under both conditions. STI, GMP and MP were the most powerful and effective drought tolerance indices preferred to select drought tolerant and yield stable genotypes. Cluster and principal component analyses were performed to classify genotypes into well-defined groups. According to cluster and principal component analyses, three clusters and two principal components were subjected to identify genotypes with their drought tolerance and yield base similarities. Identified pure lines under the first cluster and as well as under second principal component were found yield stable and drought tolerant group. From this group18294-01 and 235243-01 were found the superior pure lines fitted for both conditions followed by 224751-02, 230205-01 and 230207-01. Therefore, the current study indicated that there will be a wide opportunity to utilize the most desirable pure lines towards improvement of drought tolerance and yield stable barley varieties using different breeding programs. Especially the two superior pure lines can be recommended for their desirable characters by using them as a parent for hybridization program. However, further investigation and identification of the desirable pure lines at afield level by the aid of marker assisting selection (MAS)can be recommended to be taken into consideration.

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REFERENCES

Abo-Elwafa A, Bakheit BR. 1999. Performance, correlation and path coefficient analysis in faba bean. Assiut J. Agric. Sci. 30:77-91.

Ashraf, A., Abd El-Mohsen, M. A. Abd El-Shafi, E. M. S. Gheith, H. S. Suleiman (2015). Using Different Statistical Procedures for Evaluating Drought Tolerance Indices of Bread Wheat Genotypes Adv. Agric. Biol. 4 (1), 2015: 19-30.

Al-Abdallat A.M., Karadsheh A., Hadadd N.I., Akash M.W., Ceccarelli S., Baum M., Hasan M., Jighly A., and Abu Elenein J.M.: Assessment of genetic diversity and yield performance in Jordanian barley (Hordeum vulgare L.) landraces grown under rain fed conditions. BMC Plant Biology (2017) 17:191.

Bekele, B., F.Alemayehu and B. Lakew, "Food Barley in Ethiopia. Food Barley: Importance, uses and local knowledges," In Proceedings of the international workshop on Food Barley Improvement, 14-17 January 2002, Hammamet, Tunisia ICARDA, Aleppo, Syria, pp. 53-82, 2005.

Bouslama M and Schapaugh WT. 1984. Stress tolerance in soybean. Part 1: evaluation of three screening techniques for heat and drought tolerance. Crop Science, 24: 933-937.

CSA. (1992): Report on Agricultural sample survey. Results. Area, production, and yield for major crops 1991/92 Meher season. CenteralSatatistics Agency, Addis Ababa, Ethiopia.CSA (central statistical agency). 2005. Agricultural sample survey: area and production of major crops,Meher season. Vol. I. Addis ababa, Ethiopia

CSA (central statistical agency). 2014. Agricultural sample survey: area and production of major crops,Meher season. Vol. I. Addis ababa, ethiopia.

FAO (2013): World Food and Agriculture. Statistical Year-book.Food and Agriculture Organization of the United Nations.

Fereres E, Gimenez C, Fernandez JM.1986. Genetic variability in sunflower cultivars under drought. I. Yield relationships. Aust. J. Agric. Res. 37:573-582.

FernandeZ GCJ. 1992. Effective selection criteria for assessing plant stress tolerance. In proceeding of on the sympo. Taiwan, 13–16 Aug. 1992. By: C. G. Kuo. AVRDC.

Fischer RA and Maurer R. 1978.Drought resistance in spring wheat cultivars. Australian journal of Agriculture Research, 29: 897–912.

Gavuzzi, P., F. Rizza, M. Palumbo, R.G. Campaline, G.L., Ricciardi and B. Borghi (1997). Can. J. Plant Sci. 77:523-531.

Hossain, A.B.S., A.G. Sears, T.S. Cox and Paulsen, G.M. 1990. Desiccation tolerance and its

relationship to assimilate partitioning in winter wheat. Crop Sci., 30: 622-627.Jalil A.andSalehi M. (2012). Evaluation of drought stress indices in barley (Hordeumvulgare L.). Annals Biol. Res. 3(12):5515-5520.

Khalili M., Naghavi M.R., Pour-Aboughadareh A.R., Talebzadeh S.J. 2012. Evaluating of drought stress tolerance based on selection indices in spring canola cultivars (Brassica napus L.). J. Agric. Sci. 4: 78–85.

Khalili, M.,Pour-Aboughadareh, A., RezaNaghavi, M.:(2016). Assessment of drought tolerance in barley: integrated selection criterion and drought tolerance indices. Department of Agriculture, Payame Noor University, PO BOX 19395-3697 Tehran, Iran.

KifluTarekegn A., 2009. Agronomic evaluation of Ethiopian barley (Hordeumvulgare L.) landrace populations under drought stress conditions in low-rainfall areas of Ethiopia.

Mulukenbantayehu, 2013: study on malting barley genotypes under diverse agroecologies of north western ethiopia:adet agricultural research center, p. O. Box 08, bahirdar, ethiopia.

Nazari, L. and Pakniyat, H. (2010) Assessment of drought tolerance in barley genotypes. J. Appl. Sci., 10, 151-156.

ÖztürkLokman and DemirYavuz , In vivo and in vitro protective role of proline,* 1 Faculty of Science and Art, Department of Chemistry, Atatürk University, Erzurum, Turkey; 2 Faculty of Education, Department of Biology, Atatürk University,

Rosielle, A.A. and J. Hamblin (1981).Theoretical aspects of selection for yield in stress and non-stressenvironment. Crop Sci. 21:943-946.

Saad, FawzyF.,Ashraf A. Abd El-Mohsen, , Mohamed A. Abd El-Shafi 3and Ismaeil H. Al-Soud (2014). Effective selection criteria for evaluating some barley Crosses for water stress tolerance. Agronomy Department, Faculty of Agriculture, Cairo University, Egypt.

Samah A. Mariey, and Rania A. Khedr (2017). Evaluation of some Egyptian Barley Cultivars under Water Stress Conditions Using Drought tolerance Indices and Multivariate analysis. Barley Research Department and Crop physiologies research department, Field crop research institute, Agricultural research center, Cairo, Egypt.

Samarah N. and Alqudaha A. (2011). Effects of late-terminal drought stress on seed germination and vigor of barley (*Hordeumvulgare* L.). Jordan University of Science and Technology, Irbid, Jordan 2011

SAS Institute. 2011. SAS STAT 9.3 user's guide, vol. 5. SAS Institute, Cary, NC.

SharafiSoran,KazemGhassemi-Golezani, Soleymanmohammadi, ShahramLak and Behzadsorkhy (2014).Evaluation of barley genotypes (Hordeum vulgar L.) by drought tolerance indices and multivariate analysis, Vol. 4, No. 7, p. 117-129.

SintayehuDebebe and TesfahunAlem (2011).Response of exotic barley germplasm to low-moisture stressed environments.Proceedings of the 2nd National Barley Research and Development Review Workshop Holetta Agricultural Research Centre, Ethiopia 28–30 November 2006

Sio-Se Marde A, Ahmadi A, Poustini K and Mohammadi V (2006).Evaluation of drought resistance indices under various environmental conditions. Field Crops Res. 98: 222-229.

Subhani, G., Abdullah, M., Ahmad, J., Anwar, J., Hussain, M. and Mahmood, A. (2015) Identification of drought tolerant genotypes of barley (hordeumvulgare l.) through stress tolerance indices. J. Animal Plant Sci., 25, 686-692.

Vaezi B., Bavei V., and Shiran B. (2010). Screening of barley genotypes for drought tolerance by agro-physiological traits in field condition.Dryland Agricultural Research Station, Gachsaran, Iran. Department of Plant Breeding, Faculty of Agriculture, University of Shahrekord, Shahrekord, Iran.

YaynuHiskias, 2011.Response of barley landraces to low-moisture stress in a low-rainfall environment.Proceeding of the 2nd National Barley Research and Development Review Workshop. HARC, Ethiopia, 28-30 Nov., 2006Yosef GebreHawaryat, KebedeTeshome and SenaytWondimu (2011).Achievements of food barley breeding research for lowmoisture stressed environments of north east Ethiopia.Proceeding of the 2nd National Barley Research and Development Review Workshop. HARC, Ethiopia, 28-30 Nov., 2006.

Yousefi, B., Evaluation of genetic variations for drought tolerance in some advance lines of barley (hordeum vulgar). PHD Student of Plant Physiology, Bu-Ali University, Hamadan, Iran.ISSN 2322-4134 2015 IJFAS.

Zadoks, J.C ,Chang,T.T, Konzak, C.F "A Decimal Code for the Growth Stages of cereals", Weed Research 1974 14:415-421.