Journal of Agriculture and Crops
ISSN(e): 2412-6381, ISSN(p): 2413-886X
Vol. 8, Issue. 4, pp: 228-235, 2022
URL: https://arpgweb.com/journal/journal/14
DOI: https://doi.org/10.32861/jac.84.228.235

Academic Research Publishing Group

Original Research | Open Access

Water Deficit Stress Tolerance Assessment in Barley Cultivars Using Drought Tolerance Indices

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Article History
Received: 25 March, 2022
Revised: 28 May, 2022
Accepted: 27 June, 2022
Published: 9 July, 2022

Abstract

Crop productivity is greatly suffering from drought stress. Understanding the drought tolerance capability of the crop varieties available in a country is the prime consideration for accessibility in a very drought adaptation. The target of this analysis work was to look at the drought tolerance potentiality of five cultivated barley varieties (BARI Barley5, BARI Barley6, BARI Barley7, BARI Barley8, and BARI Barley9) through calculative drought tolerance indices. The experiment was laid down in a completely randomized design (CRD) with maintaining three replications, wherever crops were grown in check (80% of FC) and water deficit atmosphere (50% of FC). Stress Tolerance (TOL), Mean Productivity (MP), Geometric Mean Productivity (GMP), Stress susceptibility Index (SSI), Stress Tolerance Index (STI), Harmonic mean (HAM), Yield Index (YI), and Yield Stability index (STI) on grain yield in check and drought conditions were calculated. BARI Barley7 and BARI Barley8 were the foremost tolerant selection and BARI Barley9 was susceptible one based on TOL and SSI. Drought tolerance indices like MP, HAM, GMP, and TOL additionally with STI showed a high correlation with grain yield under each condition and were recognized as appropriate indices to distinguish varieties with high grain yield potential and low susceptibility to water deficit stress.

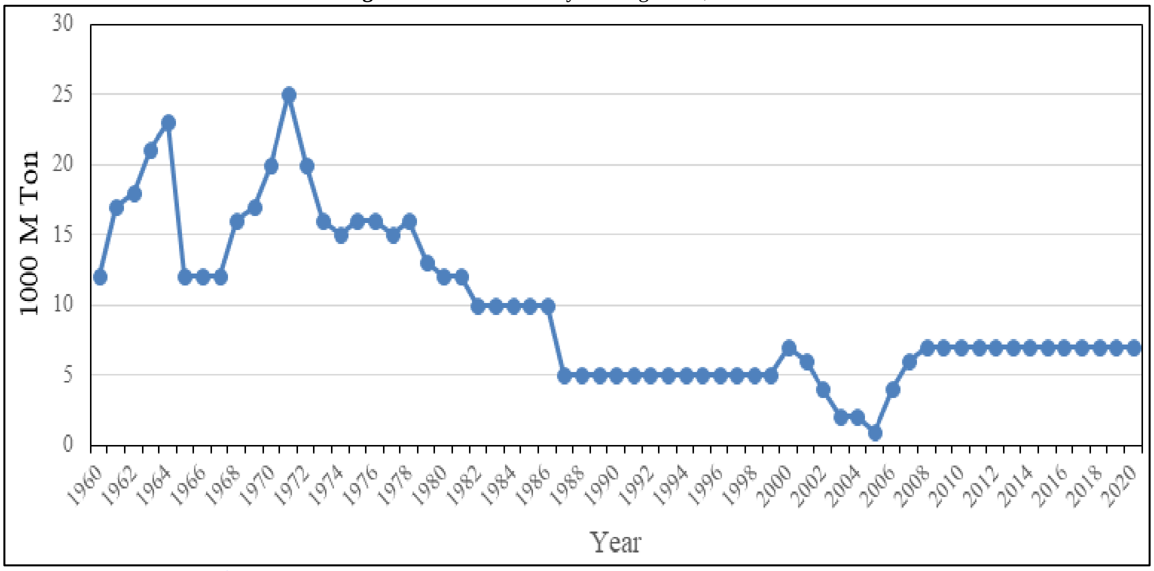
Keywords: Barley; Drought; Selection.

1. Introduction

Barley (*Hordeum vulgare* L.) is that the fourth most vital cereal crop within the world once wheat, rice and maize. It absolutely was one in all the primary grains to be domesticated by early humans and is tailored to a broad vary of agro- and profitable than the other major crops [1]. It can grow low fertile soils ecological environments and lower temperatures higher than will wheat. It are often used as a eutherian mammal feed, for malt and for making ready foods. it's a kind of edible grain that may use in bread, cereal, soup, and beer. Barley grain contains 61.8% starch, 13.1% protein, 10.8% insoluble fibre, 7.55% wetness, 4.85% soluble fibre, 4.28% pentosan, 4.26% twenty sixth glucan, 2.92% lipid, 1.89% ash and eight essential amino acids [2, 3].

The global production of barley is increasing. Within the 2019/2020 crop year, it absolutely was amounted to 156.41 million metric tons [4], whereas it absolutely was around a 140.6 million metric tons in 2018/2019. The other situation is found in Bangladesh. Barley production of Bangladesh fell bit by bit from twenty thousand tonnes in 1960 to seven thousand tonnes in 2020 (Figure 1). Over the time barley cultivation space and production area unit decreasing day by day. It should ensue to a scarcity of climate- adaptational particularly drought - tolerant barley cultivar.

Fig-1. Production of barley in Bangladesh, 1960 -2020



Data source: http://apps.fas.usda.gov/psdonline/app/index.html

In Bangladesh, barley is sometimes grown as one crop, beneath rain-fed conditions is regarding 22% of total productive land beneath barley cultivation [5]. This space regionally referred to as "Khora" areas that are characterized by low yields and severe water shortage conditions. So, this crop typically experiences water deficit and warmth stress, particularly throughout grain filling growth and development. Soil moisture content in barley growing areas in Bangladesh ranged from 40-50% FC [6]. Yield potential and its annual productivity is considerably under different same cereals [7] due to the water shortage that happens in areas of its cultivation. To enhance the livelihoods of the farmers of barley growing areas in Bangladesh, it's demanded to introduce drought-tolerant high yielding barley selection which may adapt in water deficit atmosphere.

Drought is one of the most damaging abiotic stresses to crop plants, causing growth, yield, and nutritional quality of seeds to suffer [8-11]. Climate change has emerged as one of the most important global challenges, with frequent and severe droughts occurring in recent years [12-14]. Due to this abiotic stress, over 25% of agricultural production is being hampered [15]. Drought is the most damaging abiotic factor, influencing several molecular, biochemical, physiological, morphological, and ecological features and processes at all stages of growth and development [16, 17]. Plant productivity and quality are declining drastically as a result of the water shortage [18-20], resulting in massive crop losses.

It is an awfully tough challenges for plant breeders to attain genetically higher yield beneath water-limited conditions, as compared to the progress in grain yield in favorable environments [21]. Therefore, completely different ways are suggested to produce the way for locating the most effective genotypes that have a lot of reconciling capability during a drought atmosphere. Several researchers used drought tolerance indices as screening techniques for choosing drought-tolerant genotypes which offer a live of drought supported loss of yield beneath drought conditions as compared to traditional conditions [22]. Fernandez [23] opined that these indices are either supported drought tolerance capability or status of cultivars. Drought resistance is that the relative yield of genotype compared to different genotypes subjected to an equivalent drought condition suggested by Hall [24]. Blum [25] found that drought status of a genotype is usually measured as a perform of the reduction in yield beneath drought stress. Stress tolerance (TOL) is the variations in yield between the stress and non-stress environments, mean productivity (MP) is the average yield beneath stress and non- stress environments [26] and geometric mean (GM) estimates the drought tolerance supported yield beneath drought condition. The mean is usually utilized by breeders curious about relative performance since drought stress will vary in severity during a field atmosphere [27]. Fischer and Maurer [28] projected a stress susceptibility index (SSI) of the cultivar. Stress tolerance index (STI) which may be accustomed determine cultivars that manufacture high yield beneath each stress and non-stress conditions [23]. The aim of the experiment to seek out the most effective choice criteria for distinguishing drought-tolerant barley selection to grow within the drought-prone areas of Banglaesh. Moreover, completely different stress indices were appraised to differentiate the most effective indices applicable for locating favorable selection by using advanced statistical techniques.

2. Materials and Methods

2.1. Experimental Site

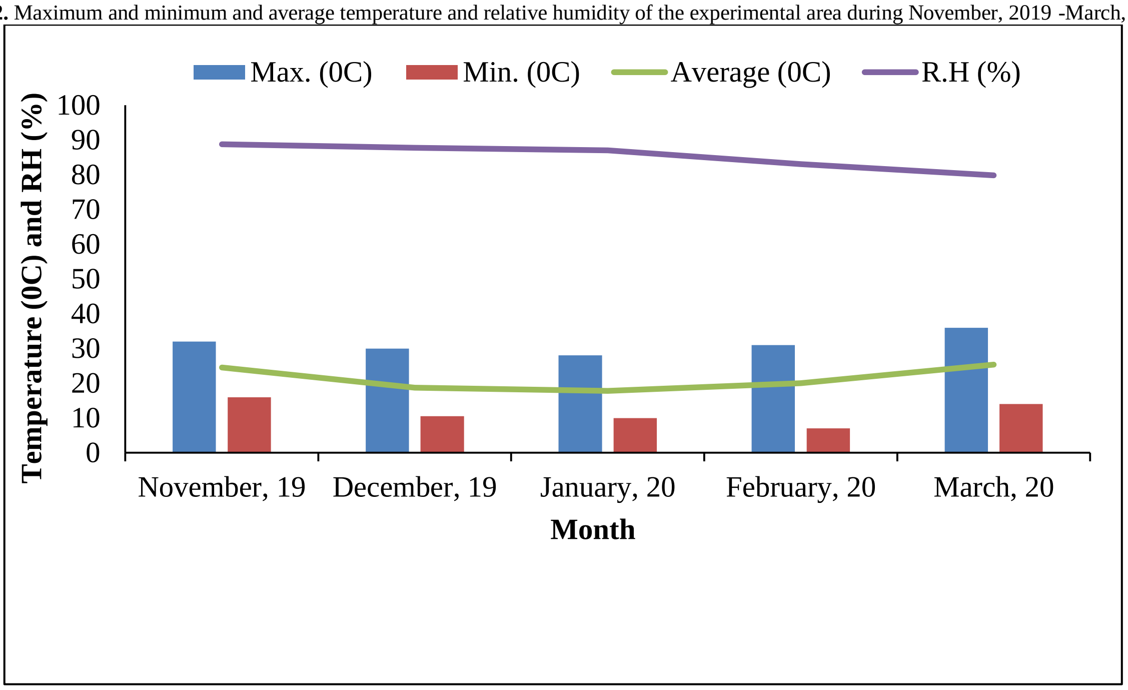
The pot experiment was arranged get into a semi-controlled surroundings (inside screenhouse) at the Department of Agronomy, Bangabandhu ruler Mujibur Rahman Agricultural University (BSMRAU), Gazipur, Bangladesh throughout November 2019 to March, 2020. The experimental site is within the centre of Madhupur Tract (AEZ 28), 24.09^{o} N latitude and 90.26^{o} E longitude at 8.4 m higher than the ocean level. Every pot (30 cm length and 24 cm diameter) was full of eleven kg soil. The chemical and physical properties of the experimental soil area unit conferred in **Error! Reference source not found.** The recommended fertilizers were applied with 0.99, 0.55 and 0.50 g urea, triple super phosphate and muriate of potash per pot corresponding to 180-100-85 kg urea, triple super phosphate and muriate of potash per hectare, respectively [29].

Table-1. Chemical and physical properties of the soil

PWP (%)	**FC (%)**	**SP (%)**	**EC (dS m^{-1})**	**Texture**	**Clay (%)**	**Silt (%)**	**Sand (%)**	
8.05	30.1	50.9	0.40	Sandy clay loam	30.78	28.00	40.51	
CONTINUOUS TABLE 1								
Exchangeable Cu (mg kg^{-1})		Extractable Mn (mg kg^{-1})	Extractable Zn (mg kg^{-1})	Extractable Fe (mg kg-1)	Exchangeable K (meq 100g^{-1})	Available P (mg 100 g^{-1})	OC (%)	pH
2.50		8.3	1.5	2.8	0.790	0.08	0.61	6.93
PWP, FC and SP : Permanent wilting point, Field capacity, soil moisture at saturation, EC: electrical conductivity of saturated paste, OC: organic carbon								

The air temperature and relative humidity of the experimentation period are presented in Figure 2.

Fig-2. Maximum and minimum and average temperature and relative humidity of the experimental area during November, 2019 -March, 2020



Source: Department of Agricultural Engineering, BSMRAU. http://bsmrau.edu.bd/age/weather-data/

2.2. Experimental Materials

Five barley cultivars (BARI Barley5, Bari Barley6, Bari Barley7, Bari Barley8 and Bari Barley9) were employed in this study. The seeds of barley varieties were collected from Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh and were seeded on November 20, 2019, and crops were fully grown following the quality cultivation techniques [30].

2.3. Experimental Factors

The experiment consisted of 2 factors: i) 5 barley cultivars and ii) 2 water regimes. 10 seeds of every cultivar were seeded in each pot. Slight irrigation was applied for seed germination. The pots were investigated regularly to identify the moisture level of the soil by using a portable digital moisture meter (POGO Soil Sensor II, Stevens, USA). After the germination, the required amount of water was added regularly to maintain the field capacity to 80% in well-watered (Control) plants, and the rest of the pots were kept in water-stressed condition by having 50% field capacity (Drought) throughout the growing season.

2.4. Experimental Design

The treatments were arranged with complete randomized design (CRD) following 3 replications.

2.5. Data Collection and Statistical Analysis

At the physiological maturity stage, crop was harvested and data on grain yield were recorded at 14% seed moisture level. Drought tolerance indices were calculated by the subsequent formula (Table 2). The recorded data were analyzed using the statistical package program CropStat 7.2 and MS workplace surpass version ten program.

Table-2. Drought tolerance indices

Index	Formula	Reference
Stress Tolerance	TOL=Yp–Ys	Rosielle and Hamblin [26]
Mean Productivity	MP=(Yp+Ys)/ 2	Rosielle and Hamblin [26]
Geometric Mean Productivity	$GMP=(Yp*Ys)^{0.5}$	Fernandez [23]
Stress Susceptibility Index	SSI=[(1– (Ys/ Yp)]/ SI	Fischer and Maurer [28]
Stress Index (SI	SI=1– (Ỹs/ Ỹp)	
Stress Tolerance Index	$STI=(Yp*Ys)/ Ỹp)^{2}$	Fernandez [23]
Harmonic Mean	HAM=[2*(Yp*Ys)]/(Yp+Ys)	Kristin, *et al.* [31]
Yield Index	YI=Ys/Ỹs	Lin, *et al.* [32]
Yield Stability Index	YSI=Ys/Yp	Bouslama and Schapaugh [33]

Yp and Ys: Grain yield of each genotype under control (non-stress) and drought stress conditions, respectively.
Ỹp and Ỹs: Mean grain yield of al l genotypes under control and drought stress conditions, respectively

3. Results

The analysis of variance (ANOVA) was enforced for measured data and it showed that no vital variations among genotypes in relevance grain yield beneath non-stress condition (Table 3). Vital variations (p ($p<0.01$) were observed among varieties under drought stress conditions.

Table-3. Analysis of variance of grain yield under control and drought conditions and different drought tolerance indices of six varieties of barley (MEAN SQUARES)

Source of variation	DF	Yp	Ys	TOL	MP	GMP
Variety	4	0.49NS	0.64*	0.21NS	0.53*	0.58*
Error	10	0.41	0.18	0.72	0.12	0.13
Total	14	0.43	0.31	0.57	0.24	0.26

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Source of variation	DF	SSI	STI	HAM	YI	YSI
Variety	4	0.38*	0.15*	1.29*	0.15*	0.12*
Error	10	0.27	0.31	0.37	0.64	0.39
Total	14	0.20	0.65	0.63	0.89	0.31

NS and *:Non-significant and significant at 5% probability levels, respectively.

Mean comparisons result showed that the best grain yield was obtained from BARI Barley7 with 3.89 g plant-1and the lowest yield was recorded from BARI Barley9 with 2.77 g plant-1 (Table 4). Under stress condition, BARI Barley7 with 2.98 g $plant^{-1}$ and BARI Barley9 with 1.76 g $plant^{-1}$, respectively had the best and lowest grain yield. However, there were no significant differences among BARI Barley5, BARI Barley6 and BARI Barley8.

Table-4. Grain yield under control (Yp) and drought (Ys) conditions and different drought tolerance indices of barley

Variety	Yp (g plant-^{1})	Ys (g plant-^{1})	TOL	MP	GMP
BARI Barley5	3.25a-d	1.98b	1.26	2.62b	2.46bc
BARI Barley6	3.53ab	2.09b	1.43	2.81ab	2.70b
BARI Barley7	3.89a	2.98a	0.91	3.44a	3.38a
BARI Barley8	3.38a-c	2.26b	0.77	2.82ab	2.63bc
BARI Barley9	2.77a-d	1.76b	1.01	2.27b	2.20c
LSD (0.05)	1.16	0.77	NS	0.63	0.66

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Variety	SSI	STI	HAM	YI	YSI
BARI Barley5	0.89	0.54b	2.34b	0.94b	0.65a-c
BARI Barley6	0.75	0.64b	2.56b	1.00ab	0.61a-e
BARI Barley7	0.61	1.03a	3.68a	1.42a	0.78a
BARI Barley8	0.70	0.68b	2.57b	0.98ab	0.67ab
BARI Barley9	0.85	0.44b	1.90b	0.83b	0.65a-d
LSD (0.05)	NS	0.32	1.11	0.46	0.35

Five barley genotypes were ranking supported drought tolerance indices. There was found a positive and important correlation (r2= zero.59) between grain yield in control (Yp) and drought stress (Ys) treatments. Calculation of tolerance indices showed that lowest stress tolerance (TOL) value and Stress susceptibility Index (SSI) value were recorded in BARI Barley7 and BARI Barley8. On the opposite hand, the best stress tolerance

(TOL) value and Stress susceptibility Index (SSI) value were found in BARI Barley5 and BARI Barley6 (Table 5).

Mean Productivity, Geometric Mean Productivity, Stress Tolerance Index, Harmonic Mean, Yield Index and Yield Stability Index values were higher in genotype BARI Barley7 and BARI Barley 8. On contrary, the lowest Mean Productivity, Geometric Mean Productivity, Stress Tolerance Index, Harmonic Mean, Yield Index and Yield Stability Index were obtained in BARI Barley5 and BARI Barley9 (Table 5).

Table-5. Ranking of 5 barley varieties in response to different drought tolerance indices

Variety	TOL	MP	GMP	SSI	STI	HAM	YI	YSI	Average Ranking
BARI Barley5	4	4	4	4	4	4	4	3	4
BARI Barley6	5	3	2	3	3	3	2	5	3
BARI Barley7	2	1	1	1	1	1	1	1	1
BARI Barley8	1	2	3	2	2	2	3	2	2
BARI Barley9	3	5	5	5	5	5	5	4	5

The positive and important correlations with Yp were determined among MP, HAM, GMP, TOL and STI (Table 6) and there was a negative and important correlation with YSI. A big and correlational statistics was additionally determined among Ys and YI, STI, GMP, HAM, STI, MP and YSI. The best correlation (r2 = 0.93) was determined between Ys and YI. The correlations of TOL (r2 = 0.44) and SSI (r2 = 0.50) with Ys was positive however non-significant. There was a positive and important correlation between TOL and SSI (r2 = 0.84) however a negative and important correlation (r2 = -0.89) was determined between TOL and YSI. There have been additionally, positive and important correlations among MP, GMP, STI, HAM and YI ($p < 0.01$). The best correlation (r2 = 0.96) was determined between MP and GMP. It had been determined positive and important correlation among GMP, HAM, STI and YI, however the best correlation (r2=0.95) was found between GMP and HAM. There was a negative and important correlation (r2=-0.84) was found between SSI and YSI. A positive and important correlation was determined among STI, HAM and YI. The positive and important correlation (r2=0.75) was found between HAM and YI. The identical relationship was additionally determined among between YI and YSI (r2=0.70).

Table-6. Correlation coefficient among grain yield under control and drought condition and different drought tolerant indices in 5 variety of barley

	Yp	Ys	TOL	MP	GMP	SSI	STI	HAM	YI	YSI
Yp	1.00									
Ys	0.59*	1.00								
TOL	0.66**	0.44NS	1.00							
MP	0.84**	0.76**	0.19NS	1.00						
GMP	0.69**	0.87**	-0.02NS	0.96**	1.00					
SSI	0.48NS	0.50NS	0.84**	0.04NS	-0.16NS	1.00				
STI	0.54*	0.89**	-0.13NS	0.87**	0.87**	0.17NS	1.00			
HAM	0.71**	0.83**	0.07NS	0.95**	0.95**	0.00NS	0.89**	1.00		
YI	0.18NS	0.93**	-0.39NS	0.65**	0.75**	0.43NS	0.87**	0.75**	1.00	
YSI	-0.51*	0.67**	-0.89**	0.04NS	0.25NS	-0.84**	0.37NS	0.20NS	0.70**	1.00

NS= non-significant,* and **= 5 and 1% level of significance, respectively.

Considering the all drought-tolerance indices ranking of barley varieties studied showed that BARI Barley7 and BARI Barley8 had the simplest position and BARI Barley9 was within the worst position in mean ranking (Table 5).

4. Discussion

ANOVA table shows a major distinction among the varieties under stress condition. This high diversity among the varieties under a stressful soil atmosphere helps us to pick drought-tolerant barley selection.

BARI Barley7 gave the best yield (2.98 g plant-1) under stress condition indicated that this genotype is comparatively drought tolerant in relevancy yield compared to different genotypes studied. On the opposite hand, BARI Barley9 is that the risk of drought in relevancy yield capability. The positive and important correlation between grain yield in check (Yp) and drought stress indicated that tolerant varieties showed their best performance under stress condition in relevancy yield.

BARI Barley7 and BARI Barley8 possess lower TOL and SSI worth, indicating that these 2 varieties had lower yield reduction due to drought stress and these indicated that these were the foremost tolerant varieties supported TOL and SSI, that their low values is indication tolerance genotypes. On the opposite hand, higher, TOL and SSI worth were found in BARI Barley6 and BARI Barley5 indicating that higher yield reduction was occurred in these 2 varieties and categorized as susceptible. BARI Barley7 and BARI Barley8 were the tolerant varieties supported of Mean Productivity (MP), Geometric Mean Productivity (GMP), Stress Tolerance Index (STI), mean value (HAM), Yield Index (YI) and Yield Stability Index (YSI). Supported the results, BARI Barley5 and BARI Barley9 were the foremost sensitive varieties. Considering the mean ranking among the varieties BARI Barley7 and BARI Barley8 were the tolerant and BARI Barley9 was thought of as at risk of drought stress.

The experimental results indicated that the foremost acceptable index to pick drought-tolerant selection is an index that encompasses a high correlation with grain yield under each controls (non-stress) and stress conditions. So, HAM, YI, STI, MP and GMP were known as acceptable indices to pick drought tolerance varieties. Karimizadeh and Mohammadi [34] opined that among drought-tolerance indices, harmonic mean value (HM), GMP, CTD and changed STI index (K2STI) are often used because the best suited indicators for screening drought-tolerant cultivars. Similar results were supported by Sanjari-Pireivatlou and Yazdansepas [35]. Many researchers opined that drought tolerance indices supported yield area unit additional helpful tools to pick stress-tolerant cultivars. STI was additional helpful so as to pick favorable cultivars below stress and non-stress conditions found by Moghadam and Hadizadeh [36]. Supported GMP and STI indices, cultivars with high yield in each stress and non-stress environments are often chosen reported by Khalili, *et al.* [37]. On the opposite hand, condition indices like SSI, TOL, and PEV and conjointly tolerant indices like STI looked as if it would be terribly helpful for extracting appropriate genotypes [38]. Similar analysis has been used for introducing tolerant and susceptible genotypes by Fernandez [23] in mung, Farshadfar and Sutka [39] in maize, Golabadi, *et al.* [40] and Talebi, *et al.* [41] in macaroni wheat, and Jamaati-e-Somarin and Zabihi-e-Mahmoodabad [42] in lentil. On the basis of yield potential in check (non-stress) and stress conditions [23] grouped the genotypes into 4: i) varieties with high production under each conditions (Group A), ii) genotypes with high production solely under non- stress conditions (Group B), iii) varieties with high production solely under stress conditions (Group C) and iv) genotypes with weak production in each conditions (Group D). Sio-Se Mardeh, *et al.* [43] valuate drought tolerance indices in wheat genotypes under completely different environmental conditions and ended that under gentle drought stress conditions MP, GMP and STI were more practical to identified genotypes. Golabadi, *et al.* [40] found important and positive correlations of Yp and (MP, GMP and STI) and Ys and (MP, GMP and STI) under each conditions in addition as important correlational statistics of SSI and TOL under moisture stress surroundings, unconcealed that choice might be conducted for high MP, GMP and STI under each environments and low SSI and TOL under moisture stress environments.

5. Conclusion

From the results, it's going to be ended that BARI Barley7 and BARI Barley8 were the comparatively tolerant and BARI Barley9 thought of as susceptible varieties supported TOL and SSI. Drought tolerance indices like MP, HAM, GMP, TOL and STI had a high correlation with grain yield under stress and non-stress conditions and were recognized as acceptable indices to select genotypes with high grain yield and low sensitivity to drought stress condition.

Acknowledgement

Grateful to Bangladesh Agricultural Research Institute for supply the seed materials.

Author Contributions

Md. Ahsan. Habib planned the research and carried out the experiment. Md. Abdul. Mannan contributed to wrote the manuscript. Dipanjoli Boral Dola data analysis, Md. Abdul. Karim, Md. Eunus. Miah, Md. Main Uddin Miah, Md. Abdullah Al Mamun, Jannatul Ferdous[4] and Hari Pratap Singh contributed to manuscript proofreading. All authors read and approved the manuscript.

Ethics

There are no any ethical issues that may arise after the publication of this manuscript.

Conflict of Interest

There is no conflict of interest of the research work.

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