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Evaluation of Finger Millet (*Eleusine Coracana* L.) Genotypes for Drought Tolerance Using Indices

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Abstract

Drought is one of the main factors limiting crop production in Ethiopia including finger millet in areas where low and erratic rainfall are common. The current study was aimed to identify drought tolerant and high yielding finger millet genotypes using drought tolerance indices. Two hundred and twenty five finger millet genotypes were evaluated in 15×15 simple lattice design with two replications at Werer Agricultural Research Center under moisture stressed and non-stressed conditions during the 2017/18 dry season. Grain yield data on moisture stressed and non-stressed treatments were used to calculate the following drought tolerance indices: drought susceptibility index (SSI), drought tolerance index (STI), geometric mean productivity (GMP), yield stability index (YSI), drought resistance index (DRI), mean productivity (MP), yield index (YI), harmonic mean (HM), stress susceptibility percentage index (SSPI) and abiotic tolerance index (ATI). Cluster, principal component and correlation analysis were computed. Genotypes Acc203401 and Acc203289 gave the highest grain yields under drought stress and non-stressed conditions, respectively. Based on the rank of genotypes using drought tolerant indices the highest grain yield was recorded for Acc203446. Positive and significant association of grain yield under both conditions was noted with SSI, YI, GMP, MP and HM suggested that these indices would be appropriate indices for screening high yielding and drought tolerant genotypes. The first two principal components (PCs) elucidated about 97.2% of the total variation. PC I, which explained about 56.1% of the total variation was due to YNS, YDS, YI, STI, GMP, MP, DRI and HM; whereas PC II described about 41.1% of the total variation, mainly due to YSI, SSI, TOL, RDI and RED. Biplot showed strong positive association among the indices DRI, YI, HM, GMP, STI and MP with grain yield under both moisture conditions. Cluster analysis classified the 225 finger millet genotypes into six clusters comprised of 1 to 70 genotypes. Generally, evaluation of genotypes using drought tolerance indices, which showed highly significant and positive association with grain yield under both moisture conditions, are reliable traits for further use in finger millet breeding program. Overall, Acc203399, Acc203401, Acc203414, Acc203423 and Acc203446 were genotypes, identified as drought tolerant, and YSI, STI, YI, GMP, GM, DRI and HM had strong and positive association with grain yield under moisture stressed condition and could be used as the most reliable indices for identifying tolerant finger millet genotypes.

Keywords: Grain yield; Indices; Moisture stress; Terminal drought

Introduction

Finger millet (*Eleusine coracana* (L.) Gaertn) (2n=36) is highly self-fertilized allotetraploid. It is grown as a small cereal in arid and semi-arid regions of Africa and Asia. It is cultivated in a wide agro-ecology ranges up to 3000 m.a.s.l.. Currently, the crop is grown and used over 25 countries of Africa and Asia, mainly as a staple food grain. It ranks fourth among small grain cereals in the world after sorghum, pearl millet and foxtail millet and is considered as an essential component of food security crop. Its average annual world production is around 4.5 million tons of grain, of which Africa produces over 2 million tons. In Ethiopia, finger millet is the 6th important cereal crop after tef, wheat, maize, sorghum and barley (CSA, 2017). Ethiopia is the second largest producer of finger millet in East and Central Africa, and millions of people directly depend on the crop as major source of energy and protein, and it is an indigenous cereal crop used as both as food grain and animal feed. Finger millet is the most important small millet and used as subsistence and food security crop. It is highly valued as a reserve food in times of famine due to its excellent storability. It is grown as a staple food grain in parts of Ethiopia where drought takes its highest loss on crop production. It is also considered as food security crop in several other parts of the country where low and erratic rainfall has been adverse on other food grains. Moreover, finger millet is often cultivated in semi-arid and arid agro-ecology, where it is frequently affected by drought. It is one of the few resilient crops that can adapt well to future climate change conditions, including drought, soil salinity and heat. Despite its importance, the national average grain yield is low, 2.3 tons ha^{-1} and far below its genetic potential yield of 3 tons ha^{-1}. Several factors, such as drought, shortage of improved varieties, lack of appropriate agronomic packages, head blast, low soil fertility and lodging contributed to its low productivity [1].

Drought is a major challenge globally and limits crop production by preventing crops from expressing its full genetic potential. It is a complex trait controlled by many genes, and its effects on crops depend on the occurrence, severity, timing and duration of drought. Drought has diverse effect on yield depending on the development stage at which it occurs. Flowering is the most sensitive stage to moisture stress, and when it occurs at this stage it resulted in delay in flowering. The genetic mechanisms that control the expression of drought tolerance in crops in general and finger millet in particular are poorly understood as it is influenced by many genes coding for various traits contributing towards drought tolerance, and is dependent on the timing and severity of moisture stress. Moreover, selection for drought tolerance is difficult because of lack of consistency in testing environments and managing interactions between stages of plant growth and environment. In Ethiopia, finger millet is mainly grown under rain fed conditions that are characterized by unpredictable rainfall, and a high incidence of abiotic stresses due to a climate change. Terminal drought is one of the most important problems that threaten finger millet production in Ethiopia.

Nowadays, there is need to increase crop productivity under drought conditions through combining knowledge gained on physiological traits, drought tolerance genetic control and the target environments. Improving drought tolerance is an important objective in many crop breeding programs, including finger millet. Screening and selection of genotypes of different crops with considerable drought stress tolerance at reproductive stage has been considered an economic and efficient means of utilizing drought-prone areas when combined with suitable management practices to decrease water loss (Rehman et al., 2005). Screening and selection of genotypes under stressed and non-stress conditions using suitable drought tolerance indices is crucial to design appropriate breeding methods for identification of drought tolerant cultivars. Use of drought tolerance indices, namely: Yield Stability Index (YSI); Stress Susceptibility Index (SSI) and Relative Drought Index (RDI); Yield Index (YI); Stress Tolerance Index (STI) and Geometric Mean Productivity (GMP); Mean Productivity (MP); Tolerance Index (TOL); Drought Resistance Index (DRI), and Stress Susceptibility Percentage Index (SSPI) and Abiotic Tolerance Index (ATI); Harmonic Mean (HM), and Reduction % (RED) are believed to be simple and reliable methods for identification of tolerant genotypes. In Ethiopia, a large number of finger millet collections are available, but most of these collections have not yet been well characterized and evaluated under drought conditions. And also, previous information on evaluation of a large number of finger millet genotypes using drought tolerance indices is limited. Furthermore, breeding for drought tolerance and identification of well-adapted genotypes is among the major goals of the national finger millet breeding program of Ethiopia to drought-prone finger millet growing environments of the country. Hence, the objective of this study was to identify drought tolerant finger millet genotypes and suitable drought tolerance indices associated with low moisture stress [2].

Materials and Methods

Description of experimental site

The experiment was conducted at Werer Agricultural Research Center (WARC) under irrigation during the 2017/18 dry season. WARC is located in Middle Awash Valley with 90°60'N latitude and 400°9'E longitude at an altitude of 740 meters above sea level (m.a.s.l.). It receives a mean annual rainfall of 533 mm, with average minimum and maximum temperature of 19.2°C and 34.4°C, respectively. It is considered as dry lowland environment similar to drought prone finger millet production areas of the country. The soil of the experimental site was Vertisol.

Experimental plant materials

Two hundred fifteen finger millet genotypes and ten released varieties obtained from the Ethiopian Biodiversity Institute (EBI) and Adet Agricultural Research Center (AARC),

respectively, were used for this study. The genotypes were selected based on their adaptation to low moisture stress (altitude range from 400 to 1250 m.a.s.l.) and are considered as lowland types.

Experimental design and layout

The genotypes were evaluated in 15 × 15 simple lattice design with two replications in two moisture regimes (drought stressed and non-stressed) using irrigation. Stress was induced from anthesis (first flower opening stage) until physiological maturity in order to simulate terminal moisture stress, while the genotypes under non-stressed were fully irrigated using surface furrow irrigation at a week interval till maturity. The non-stressed experiment received recommended irrigations until physiological maturity. Each entry, consisted of two rows of 2 m length, 0.4 m wide with a plot size of 0.8 m^2. A spacing of 1 m between incomplete blocks and 2 m between adjacent replications was used. Seeds were sown in rows with manual hand drilling at a rate of 15 kg ha^{-1}. Plots were fertilized with 60 kg ha^{-1} P_2O_5 and 60 kg ha^{-1} N. The former was applied in the form of DAP at planting and N was applied in the form of Urea twice at planting and tillering stage (40 to 45 days after planting). All other agronomic and cultural practices were applied as per recommendations for finger millet.

Data collection

Data were recorded on grain yield from the two treatments of drought stressed and non-stressed from each of the genotype.

Data analyses

Data on grain yield of the two treatments (non-stressed and drought stressed) were analyzed separately using GLM model by SAS 9.0 (SAS Institute, 2004). Analysis of variance, correlation, cluster and Principal Component Analysis (PCA) among indices (Table 1) under drought stress and non-stressed conditions were computed using Minitab version 17 based on correlation distance matrices. To identify drought tolerant genotypes, a rank sum (RS) was estimated as: Rank Sum (RS) = Rank mean ($\bar{R}$) + Standard deviation of rank (SDR), SDR= $(S^2i)^{0.5}$.

Results and Discussion

Grain yield performance of finger millet

Analysis of Variance (ANOVA) showed highly significant differences (P<0.01) among finger millet genotypes for moisture level and their interactions (Table 2) on grain yield. This indicates the

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existence of high possibility to identify genotypes that are suitable for both drought stressed and non-stressed environments. Mean performance of the 225 finger millet genotypes for grain yield under moisture stressed and non-stressed conditions are summarized on Table 5. Mean grain yields of genotypes varied from 397 to 2918 kg ha^{-1} under stressed conditions, and 1130 to 4076 kg ha^{-1} under non-stressed conditions (Table 3 and 5). The mean grain yields varied from 1887 kg ha^{-1} to 2653 kg ha^{-1}under stressed and non-stressed conditions, respectively, and brought about 29% grain yield reduction. Various authors conducted drought screening experiments on different crops using drought tolerance indices and reported the existence of significant grain yield differences among genotypes [3].

Based on drought tolerant indices, genotypes Acc203257, Acc203289, Acc203334, Acc203399, Acc203401, Acc203405, Acc203414, Acc203423, Acc203445 and Acc203446 showed the highest grain yield under stressed condition, whereas Acc203257, Acc203259, Acc203317, Acc203326, Acc203399, Acc203401, Acc203414, Acc203413, Acc203423 and Acc203446 had the highest grain yield under non-stressed condition. Genotype Acc229469, Acc203542, Acc235844, Acc203443 and Acc203425 recorded the lowest grain yield under stressed condition, while Acc229469, Degu, Acc203310, Acc214995 and Acc214996 recorded lowest under non-stressed condition. On the contrary, Acc203257, Acc203259, Acc203326, Acc203398, Acc203401, Acc203414, Acc203423, Acc203445, Acc203253, Acc203429, Acc203480 and Acc203496 were found to be high yielders under both moisture conditions. Acc229469 gave the lowest grain yield in both stressed and non-stressed environments. Overall, the grain yield potential of genotypes varied under stressed and non-stressed conditions. Similarly, Mursalova et al. (2015) recorded the highest grain yield for genotypes G13 (7.066 t ha^{-1}) and the lowest for G4 (2.236 t ha^{-1}) under stressed condition, whereas under non stress, genotypes G7 (4.996 t ha^{-1}) and G4 (1.228 t ha^{-1}), respectively recorded the highest and lowest grain yield winter bread wheat genotypes.

Source of variations	**DF**	**Mean Squares**
Irrigation	1	131928004.6
Replication	1	92100.8
Block	28	118886
Genotype	224	1272133.2
Irrigation genotype	224	139063.6
Error	420	130175
CV (%)		15.894

Table1: Mean squares from analysis of variance on grain yield for 225 finger millet genotypes tested under drought stressed and non-stressed treatments at WARC, 2016/17.

Mean grain yield under stressed /kg/ha						Mean grain yield under non-stressed /kg/ha					
Genotypes	Yds kg/ha	R	Genotypes	Yds kg/ha	R	Genotypes	Yds kg/ha	R	Genotypes	Yds kg/ha	R
Acc203399	2918	1	Acc229440	1076	218	Acc203326	4076	1	Acc203276	15549	218
Acc203423	2898	2	Acc214996	1040	219	Acc203257	4073	2	Acc203517	1552	219
Acc203445	2875	3	Acc203425	959.3	220	Acc203423	4072	3	Acc214996	1502	220
Acc203405	2870	4	Acc229469	852.4	221	Acc203317	4070	4	Acc203425	1466	221
Acc203334	2834	5	Acc203424	1824	222	Acc203257	4042	5	Acc214995	1491	222
Acc203446	2833	6	Acc235844	791.5	223	Acc203399	4041	6	Acc203310	1415	223
Acc203401	2832	7	Acc203512	450	224	Acc203259	4027	7	Degu	1332	224
Acc203257	2830	8	Acc203542	397	225	Acc203414	4012	8	Acc229469	1130	225

Table2: Mean value of grain yield for the top and least eight finger millet genotypes under moisture stressed and non-stressed conditions evaluated at WARC during the 2016/17 dry season.

Tolerant genotypes							**Susceptible genotypes**						
Genotypes	**Yns**	**Yds**	**MR**	**SDR**	**RS**	**R**	**Genotypes**	**Yns**	**Yds**	**MR**	**SDR**	**RS**	**R**
Acc20344	4104	2833	34.6	39.9	74	1	Acc203425	1466	959	172	40.2	211.8	216
Acc20340	4109	2832	34.0	41.8	76	2	Acc203321	1576	1084	173	41	213.7	217
Acc20332	4076	2776	35.4	41.2	76	3	Acc203517	1552	1138	180	37.2	214.9	218
Acc20349	3988	2805	40.2	38.0	77	4	Acc203310	1415	985	179	41.1	220.4	219
Acc20342	4072	2898	36.2	41.1	77	5	Acc214995	1491	1258	192	39.6	220.7	220
Acc20325	4073	2830	36.2	41.1	77	6	Acc203433	1629	1255	182	39.8	221.2	221
Padet	3993	2745	40.2	40.5	78	7	Acc203459	1636	1299	186	39.4	224.6	222

Acc 203 48	399 8	270 2	39. 7	39. 8	79	8	Acc 203 402	160 6	125 5	185	41. 1	225 .7	223
Acc 203 31	407 0	269 2	37. 6	41. 2	79	9	De gu	133 2	987	187	41	228 .4	224
Acc 203 25	402 7	282 4	38. 0	40. 9	79	10	Acc 203 276	155 49	122 5	189	41. 2	230 .0	225

Table3: The top moisture stressed tolerant and susceptible finger millet genotypes using rank sum of indices under moisture stressed and non-stressed conditions evaluated at WARC during the 2016/17 dry season.

Correlation among grain yield and drought tolerance indices

Correlation coefficients to identify the most effective indices associated with drought tolerance genotypes are indicated. The grain yield under stressed condition showed positive and significant association with grain yield under non-stressed treatment, suggesting that high yielding genotypes under non-stressed would also perform similarly under stressed environment. Grain yield showed highly significant and positive association with YNS, YSI, STI, YI, GMP, GM, DRI and HM in stressed environment. In contrast, grain yield showed significant and negative association with SSI, RDI and RED. Hence, high values of YSI, YI, STI, GMP, GM, DRI and HM, and low value of TOL and SSI were identified as drought tolerance selection criteria and could be used to select drought tolerance genotypes. Similar to this finding, reported positive and significant correlation between STI, MP, GMP and YSI in wheat. Similarly, noted significant and positive associations among MP, STI, GMP, HM, YI and DRI in sunflower. Found significant and positive correlations among DI, STI, GMP, HM, MPI, MRP, RE, RDI, YSI and YI with grain yield in rice under stressed conditions found positive association of grain yield with STI, GMP, MP and HM, while it was negatively correlated with SSI, TOL and DSI in tef. Grain yield showed highly significant and positive correlation with YDS, STI, YI, STI, GMP, GM, TOL, HM, DRI and SSPI under non-stressed conditions, suggesting that indirect selection of genotypes for drought tolerance based on high yielding potential under non-stressed conditions would be effective.

This result is in line with the findings of who found significant and positive correlation of seed yield with TOL, MP, STI, SSI and GMP in safflower under non-stressed treatment. Positive and significant association of grain yield under stressed and non-stressed conditions were exhibited by STI, YI, GMP, MP, DRI and HM, suggesting these indices would be appropriate indices for screening high yielding and drought tolerant genotypes under both moisture conditions. This finding was in agreement with that of Ali and El-Sadek who reported significant and positive associations of grain yield in both treatments with MP, GMP and STI in wheat. Grain yield in stress and non-stressed conditions had significant and positive correlation with STI, GMP, MP and YI in corn. Positive association among grain yield in both treatments with STI, MP and GMP in barley. Similarly, positive correlation among indices and grain yield in both treatments were reported in durum wheat in barley.

Rank of genotypes using drought tolerance indices

Due to lack of consistency among the drought tolerance indices in discriminating drought tolerant and susceptible genotypes, selection based on multiple indices instead of single criteria would be indispensable for identifying drought tolerant genotypes in finger millet. Despite, the inconsistency of drought tolerance indices in determining the drought tolerant levels of the genotypes, SSI, RDI and SSI ranked the genotypes relatively in a similar way showing that these indices can be used interchangeably. Similarly, STI and GM showed uniform ranking pattern. GMP, MP, HM, YSI and YI categorized genotypes in a similar trend. Based on rank of genotypes, genotypes Acc203257, Acc203259, Acc203326, Acc203399, Acc203401, Acc203414, Acc203423, Acc203446, Acc203253, Acc203429, Acc203480 and Acc203496 were identified as the highest yielding and drought tolerant genotypes. On the other hand, Acc229469, Acc203542, Acc235844, Acc203443 and Acc203425 were identified as the most sensitive genotypes, and also lowest based on the rank of genotypes (Tables 3).

Principal component analysis (PCA)

Principal components (PCs) analysis of drought tolerance indices, grain yield under stress and non-stressed conditions of 225 finger millet genotypes are summarized on Table 7. The data were standardized to mean zero and variance of one before principal component analysis. PCs with eigenvalue greater than unity and component loadings greater than ± 0.3 were considered to be meaningful and valuable (Hair et al., 1998). The first two PCs with eigenvalues greater than one, elucidated about 97.2% of the total variation. PCI which explained about 56.1% of the total variation, and majority of the variations were due to YNS, YDS, YI, STI, GMP, MP, DRI and HM. Genotypes in PC1 are characterized by high grain yield and drought tolerance. Thus, these indices are considered as useful ones to screen high yielding and drought tolerant genotypes under both moisture conditions.

PCII described about 41.1% of the total variation mainly due to YSI, SSI, TOL, SSPI, RDI, RED and ATI (Table 4). The genotypes were drought sensitive and high yielding under non-stressed treatment but they gave low grain yield under stressed environment. Hence, this shows that selecting genotypes with high PCI and low PCII would be appropriate for both drought stress and non-stressed conditions. Accordingly, genotypes Acc203257, Acc203289, Acc203334, Acc203399, Acc203401, Acc203405, Acc203414, Acc203423, Acc203445 and Acc203446 were recorded as high yielding and drought tolerant. Genotypes Acc203330, Acc203254, Acc203272, Acc203318, Acc203477 and Acc203592 with low PCI and high PCII would be specifically adapted to non-stressed condition (Table 5). This study is in agreement with previous findings of Golabadi et al. (2006) in durum wheat, Jalilvandy and Rozrokh (2013) in wheat, Aliakbari et al. (2014) in rapeseed cultivars, and Ali and El-Sadek (2016) in wheat [4].

Biplot showed strong positive association among the indices DRI, YI, HM, GMP, STI and MP with grain yield under both moisture conditions (Figure 1). Therefore, these indices could be used as useful selection criteria for screening for drought tolerance with high grain yield stability in both environments. Similar results were reported using MP, GMP, STI and YI on Sorghum by Tesfamichael et al. (2015). Hence, genotypes Acc203257, Acc203399, Acc203401, Acc203414, Acc203423 and Acc203446 are high yielders and appropriate for both environmental conditions.

Variables	PC1	PC2

Grain yield under non-stressed treatment (YNS)	0.3	-0.199
Grain yield under stressed treatment (YDN)	0.343	0.026
Yield stability index (YSI)	0.134	0.366
Stress susceptibility index (SSI)	-0.138	-0.366
Yield index (YI)	0.343	0.026
Stress tolerance index (STI)	0.333	-0.091
Geometric mean productivity (GMP)	0.338	-0.074
Mean productivity (MP)	0.333	-0.103
Tolerance index (TOL)	0.043	-0.397
Drought resistance index (DRI)	0.31	0.157
Abiotic tolerance index(ATI)	0.206	-0.311
Stress susceptibility percentage index (SSPI)	0.043	-0.397
Harmonic mean (HM)	0.341	-0.049
Relative drought index (RDI)	-0.148	-0.306
Reduction %.(RED)	-0.138	-0.366
Eigenvalue	8.1475	6.17
Proportion	0.561	0.411
Cumulative	56.1	97.2

Grain yield under stressed revealed strong and positive association with DRI and YI. Genotypes like Acc203289, Acc203414, Acc203399, Acc203423 and Acc229469, with high PCI and low PCII value were found to be best performing under stressed environment (Figure 2). Biplot also revealed negative correlation among grain yield under stressed with SSI, RDI and RED. Hence, these indices can be used to select genotypes sensitive to drought stress. Genotypes such as Acc203320, Acc203349, Acc203365, Acc203488, Acc203529 and Acc203327 were found to have moderate performance in non-stressed and poorly performing under stressed conditions. Grain yield under non-stressed showed strong and positive association with ATI, indicating these indices are useful to identify specifically adapted genotypes for non-stressed environment. Strong negative association of YSI was noted with RDI, RED and SSI as indicated by a large obtuse angle between their vectors. The current study suggested that biplot analysis based on the first two PCs are reliable in identifying drought tolerance genotypes in wheat, in durum wheat, and in barley.

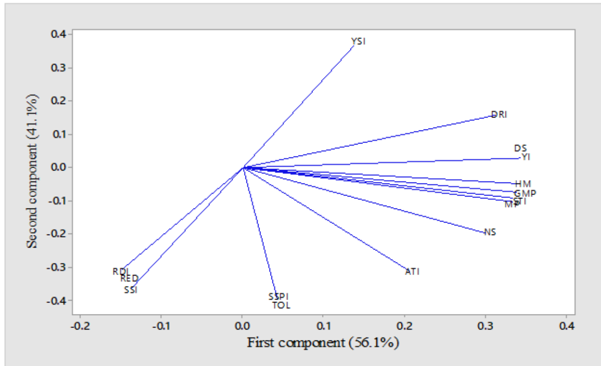

Figure1: The biplot of drought tolerance indices between 225 finger millet genotypes evaluated at WARC, 2017/18.

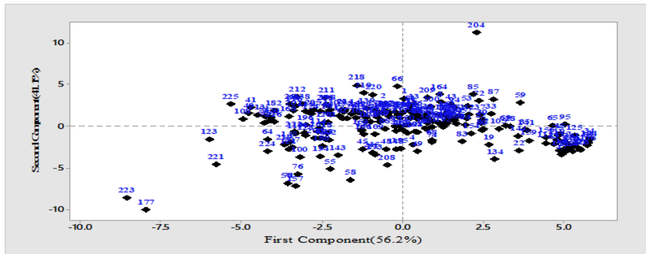

Figure2: Biplot of PCI and PCII loadings of the principal component analysis showing the relationship of 225 finger millet genotypes for grain yield under drought stressed and non-stressed conditions using drought tolerance indices.

Cluster Analysis

Cluster analysis was carried out based on average linkage methods using 13 drought tolerance indices and grain yield under stressed and non-stressed conditions to estimate phenotypic similarity of genotypes. The cluster analysis grouped the 225 finger millet genotypes into six clusters consisting of 1 to 70 genotypes (Figure 3). Cluster I, II, III, IV, V and VI consisted of 44, 70, 36, 48, 26 and 1 genotypes, respectively. Genotypes in the first and second clusters were characterized by moderate grain yield in non-stressed conditions and produced grain yield below average under stressed environments. Genotypes in these cluster had moderate value of the drought tolerance indices. These clusters included the highest value of TOL, ATI, SSPI and RDI, but moderate values of YI, STI, GMP, MP and HM indices. Cluster III contained genotypes with high grain yield in non-stressed and moderate grain yield in the stress environments. High values of YSI, SST, SSI, GMP, MP, HM, TOL, SSPI, YI and DRI indices were observed in this cluster. Therefore, genotypes in this cluster would be more suitable to non-stressed conditions [5].

Genotypes found in Cluster IV were characterized by genotypes with low grain yield under both moisture conditions. These genotypes showed low values for STI, SSI, TOL, HM, GMP, MP, ATI, SSP, RDI, and high for YSI, YI and DSI. Hence, genotypes in this cluster poorly performed under both moisture conditions. Cluster V had the highest grain yield under both moisture conditions, associated with STI, HM, GMP, MP and YSI indices. Hence, the genotypes in this cluster could be more suitable to both moisture conditions. Genotypes Acc203257, Acc203399, Acc203401, Acc203414, Acc203423 and Acc203446 were grouped together in this cluster, and resulted in high mean grain yield under both moisture regimes and identified as drought tolerance. Cluster VI contained one genotype characterized by low grain yield under moisture stressed and produced moderate grain yield under non-stressed condition. The genotype in this cluster showed high value for YSI, YI and DRI and low values for SSI, STI, GMP, MP, TOL, ATI, SSP, HM and RDI.

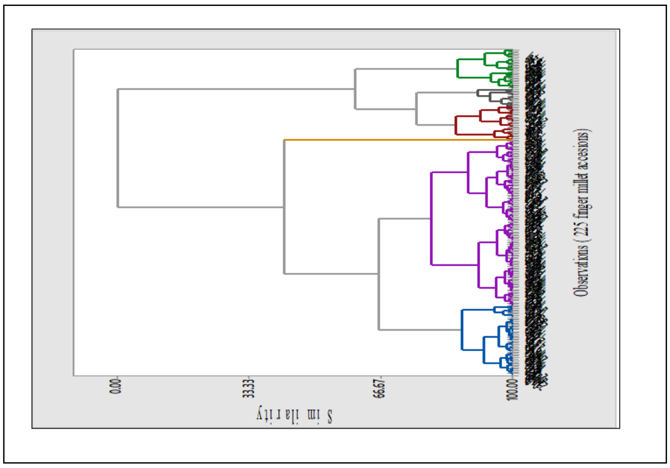

Figure3: Dendrogram based on Ward Method showing the genetic similarity between 225 finger millet genotypes tested at WARC in 2016/17 dry season under drought stressed and non-stressed conditions.

Conclusion

Grain yield reduction of 29% is recorded due to terminal moisture stress. Screening based on multiple drought tolerance indices can be valuable for identifying drought tolerant and high yielding finger millet genotypes under both moisture conditions. Grain yield indicated positive and highly significant association was noted with YNS, YSI, STI, YI, GMP, GM, DRI, ATI and HM, whereas significant and negative association with SSI, RDI and RED under stressed conditions. Positive and significant association of grain yield under stressed and non-stressed conditions with STI, YI, GMP, MP, DRI, HM and ATI suggested that these indices would be appropriate indices for screening high yielding and drought tolerant genotypes under both moisture conditions.

PCA and biplot analysis revealed strong correlation of grain yield under moisture stressed and non-stressed conditions with STI, GMP, MP, YI, DRI and HM. Therefore, these indices separated drought tolerant genotypes with high grain yield. Cluster analysis based on drought tolerance indices grouped the 225 genotypes into six clusters consisting of 1 to 70 genotypes. Genotypes in cluster V had the highest grain yield under both moisture conditions with suitable drought tolerance. Based on correlation, cluster, PCA and biplot analysis STI, GMP, MP, YI, DRI and HM showed more reliable indices, and are recommended to select genotypes with drought tolerance and high grain yield under both moisture conditions. Overall, the results need to be further validated using multi-locations and multi-season data to confirm performance repeatability and for future recommendation of genotypes.

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References

1. Agboma PC, Jones MJK, Rita PH, Peru E (1997) Exogenous glycinebetaine enhances grain yield of maize, sorghum and wheat grown under two supplementary watering regimes. J Agron Crop Sci 178: 29-37.
2. Arshadi A, Karami E, Sartip A, Zare M, Rezabakhsh P (2018) Genotypes performance in relation to drought tolerance in barley using multi environment trials. Agron Res 16: 5-21.
3. Blum A (2011) Drought resistance-Is it really a complex trait?. Funct Plant Biol 38: 753-757.
4. Bouslama M, Schapaugh WT (1984) Stress tolerance in soybean: Evaluation of three screening techniques for heat and drought tolerance. Crop Sci 24: 933-937.
5. Dehbalaei S, Farshadfar E, Farshadfar M (2013) Assessment of drought tolerance in bread wheat genotypes based on resistance/tolerance indices. Int J Agricul Crop Sci 5: 2352-2358.