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Screening of Drought Tolerant Bread Wheat (*Triticum aestivum* L.) Genotypes using Yield Based Drought Tolerance Indices

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ድርቅ የዳቦ ስንዴ ምርት ከሚቀንሱ ሂወት የሌላቸዉ ማነቆዎች በዋናነት ይጠቀሳል። የዘር ሀብቶች እና የምርጫ ዘዴዎች ድርቅን የሚቋቋሙ ዝርያዎች በምርምር ለማሻሻል ከሚያስፈልጉን ቅድመ ሁኔታዎች አንዱ ናቸው። የዚህ ጥናት ዓላማ የነበረው ድርቅን ሊቋቋሙ የሚችሉ ዝርያዎች ለመምረጥ የሚያስፈልጉ ዋና ወና የድርቅ መቋቋም ኢንዲሰስ ማወቅ እና ድርቅን የሚቋቋሙ የዳቦ ስንዴ ዝርያዎች መለየት ነው። 256 የዳቦ ስንዴ ዝርያዎችን በሲምፕል ላቲስ ዲዛይን በሁለት ድግግሞሽ ተዘርተዉ ሁለቱም ሙከራዎች 50% እስኪያጎጠጉጡ ድረስ እኩል የመስኖ ቁጥር እና ተመሳሳይ የውሃ መጠን እየተሰጣቸው የመጣ ሲሆን አንደኛው ሙከራ ተጨማሪ ሁለት ግዜ ከ50% ማጎጥጎጥ በኋላ ሁለት ግዜ ዉሀ የተሰጠው ሲሆን ሁለተኛው ሙከራ ደግሞ ከ50% ማጎጥጎጥ በኋላ ዉሃ በመከልከል የተገመገሙ ሲሆኑ በዝርያዎቹ መካከል ከፍተኛ የሆነ የምርት ልይነት በሁለቱም ሁኔታዎች (በበቂ የዉሀ መጠን እና የውሀ እጥረት ባለበት ሁኔታ) ታይቷል። የዋና ክፍሉ ትንተና እና የእረስ በርስ ግንኙነት ትንተናዎች እንደሚያሳዩት አማካይ ምርታማነት፣ ጂኦሜትሪክ አማካይ ምርታማነት ፣ የእህል ምርት ኢንዴክስ እና የድርቅ መቆጣጠሪያ ኢንዴክስ ድርቅን የሚቋቋሙ ዝርያዎች ለመምረጥ በዋናነት ከሚያስፈልጉን የድርቅ ኢንዴክስ ናቸዉ ። በተጨማሪም እነዚህ ኢንዴክሶች ከምርት ጋራ ከፍተኛ የሆነ ግንኙነት በሁለቱም ሁኔታዎች አላቸው። ይህ የሚያሳየን እነዚህ የድርቅ ኢንዴክሶች የተሻሻሉ ዝርያዎች ለመምረጥ አስፈላጊዎች መሆናቸውን ነው። በዚህ መሰረት ዝረያ 147 እና ዝርያ 100 ድርቅን በተሻለ መጠን የሚቋቋሙ ዝርያዎች ተብለው የተመረጡ ናቸዉ ። ስለዚህ እነዚህ ዝርያወች ድርቅን የሚቋቋሙ የዳቦ ስንዴ ምርምር ማሻሻያ ውስጥ አስገብተን ልንጠቀምባቸው እንደምንችል ይጠቁመናል። በተጨማሪ የክላስተር ትንተና በጥናቱ ውስጥ የተካተቱ 256 ዝርያዎች ዘጠኝ ቦታ ሲመድባቸው ክላስተር ዘጠኝ አራት ዝርያዎች (18፣137፣100 እና 147) የያዘ ሲሆን እነዚህ ዝርያዎች በሁለቱም ሁኔታዎች ከፍተኛ ምርት የሰጡ ሲሆኑ በተጨማሪም ከፍተኛ አማካይ ምርታማነት፣ ጂኦሜትሪክ አማካይ ምርታማነት ፣ የእህል ምርት ኢንዴክስ እና የድርቅ መቆጣጠሪያ ኢንዴክስ አላቸው።

Abstract

Drought is one of the major abiotic constraints seriously influencing bread wheat (Triticum aestivum L.) genotype production in Ethiopia. Genetic resources and selection methodologies are among the prerequisites to improve the efficiency of breeding for drought tolerance. The objectives of this study were to determine the principal selection indices for drought and to identify drought tolerant genotypes under drought conditions. 256 bread wheat genotypes were evaluated using a simple lattice design with two replications. Number of irrigation and the amount of water supply was similar for both water regimes until 50% heading stages. Non-stressed plots were irrigated 2 times after 50% heading stage, while stressed plots received no water in order to simulate terminal drought. Genotypes showed highly significant differences ($P \leq 0.01$) for grain yield under non-stressed and stressed conditions. Principal component and correlation analyses revealed mean productivity, geometric mean productivity, grain yield index and stress tolerance index as the principal indices highly correlated with grain yield in the stressed and non-stressed environments, indicating their suitability for identifying superior genotypes. Genotypes 147 and 100 were identified as more tolerant, which could be useful for drought stress tolerance breeding. Cluster analysis classified the genotypes into nine clusters. Cluster IX consisted of four genotypes, 18,137,100 and 147 gave high grain yield under both the moisture -stressed and non-stressed conditions with high value of mean productivity, geometric mean productivity, grain yield index and stress tolerance index. Therefore, breeders can select suitable genotypes under water-stressed conditions and compare their performance under non-stressed conditions using MP, GMP, YI and STI indices as a means to combine information on performance under both conditions.

Introduction

Wheat (*Triticum aestivum* L.) is a major cereal crop in many parts of the world including Ethiopia. Ethiopia is the second largest wheat producing country in Sub-Saharan Africa next to South Africa (Demeke and Di marcantonia 2013). Wheat annual production was more than 4.6 million tons of grain on 1.7 million hectares of land which accounted for 13.4% of total land allotted to cereals. Although the productivity of wheat has increased in the last few years in Ethiopia, the national average productivity is still 2.7 tons per hectare (CSA, 2018). Global wheat production in the major production regions is being threatened by recurrent drought that is predicted to increase with climate change (Li *et al*., 2009). Drought stress remains the leading constraint to attain crop yield potential in areas with limited and erratic rainfall. Byerlee and Morris (1993) and Sahar *et al*. (2016) reported a grain yield reduction of 42% and 50%, respectively. Ethiopian agriculture is mainly rain-fed and the rains are becoming more erratic with a trend of starting late and ceasing early in the season, which could make the sector vulnerable to drought and other natural calamities (Cheung *et al*.2008).The production loss due to both biotic and abiotic factors coupled with the increasing population has made it difficult to attain food security in the country.

Drought tolerant wheat varieties are the ultimate means of safeguarding the crop against adverse effects of drought. However, breeding for drought tolerance is affected by several factors, such as the quantitative nature of inheritance of drought tolerance (Blum, 2011), availability of suitable genetic resources, a well-suited stress screening environment and high-throughput selection methods (Araus and Cairns 2014).The relative yield performance of genotypes in stressed and non-stressed environments seems to be a common starting point in the identification of desirable genotypes for drought conditions (Nouri *et al*., 2011). Drought indices which provide a measure of drought based on loss of yield under drought conditions in comparison to normal conditions have been used for screening drought tolerant genotypes. Rosielle and Hamblin (1981) introduced stress tolerance index (TOL) based on the differences in yields measured under non- stress (Yp) and stress (Ys) conditions. Fischer and Maurer (1978) proposed a stress susceptibility index (SSI) and showed that it is not independent of yield potential. Genotypes with higher stress susceptibility index and stress tolerance index values are considered less drought tolerant. Rosielle and Hamblin (1981) proposed mean productivity index (MP) as the average of yield under non- stress (Yp) and stress (Ys) conditions. However, mean productivity has an upward bias when there are larger differences between yield under noon-stress (Yp) and yield under stress (Ys) conditions.

Geometric mean (GM) is mostly used by breeders interested in relative yield, because drought stress can vary in time of occurrence, severity and duration in field environment over years (Ramirez and Kelly, 1998).The geometric mean productivity (GMP) proposed by (Fernandez, 1992) is less sensitive to extreme values, is a better indicator than mean productivity (MP) for separating superior genotypes. Fernandez (1992) defined stress tolerance index (STI), which can be used to identify genotypes, which produce high yields under both conditions. Selection based on stress tolerance index (STI) and geometric mean productivity (GMP) will be resulted in genotypes with higher stress tolerance and yield potential (Fernandez, 1992). Yield stability index (YSI) suggested by (Bouslama and Schapaugh 1984) and yield index (YI) suggested by (Meysam and Farshadfar 2015) were used to evaluate the stability of genotypes under stress and non- stress conditions. Ramirez and Kelly (1998) reported that selection based on a combination of geometric mean productivity (GMP) and stress susceptibility index (SSI) provide a more desirable criterion for improving drought tolerance in common bean. The ability of drought tolerance indices to identify genotypes with high performance under both non-stress and stress conditions has also been evaluated using both multivariate statistical analysis and the correlations of the indices with yield in different crop species such as bread wheat (Dorostkar *et al*., 2015), durum wheat (Mohammadi *et al*., 2016), barley (Nazari and Pakniyat, 2010), safflower (Bahrami *et al*., 2014), however very limited work has been reported in Ethiopia. So to improve wheat yield and its stability in stress environments, there is a need to identify selection indices able to distinguish high yielding wheat genotypes in these conditions. Therefore, the objectives of this study was to determine the principal drought selection indices and identification of drought tolerant bread wheat genotypes.

Materials and Methods

The Study Area

The study was conducted at middle Awash of Afar regional State at Werer Agricultural Research Center which is 280km far from Addis Ababa, Ethiopia. The center is located at 9°20’31" N latitude and 40°10’11" E longitude with an altitude of 740 m.a.s.l. The area receives annual mean rainfall of 533mm with mean maximum and minimum temperature of 34.4^{0}C and 19.2^{0}C respectively. Slope gradients are generally very low and predominantly lying in the range between 1 and 2%. The predominant soil types are Vertisols and Fluvisol shaving alluvial origin deposited from Awash River.

Plant Materials

The plant materials used in this study comprised 256 bread wheat genotype including 171 spring bread wheat from advanced yield trial (SBWAYT), 64 spring bread wheat from observation nursery for heat tolerance (16th HT-SBWON), 14 spring bread wheat from yield trial for dry-land environments (16th DSBWYT) and 1 spring bread wheat from yield trial for dry-land environments (17th DSBWYT) were obtained from the International Center for Agricultural Research in the Dry Areas (ICARDA) and in addition 6 improved bread wheat varieties were included.

Experimental Design and Field Management

The design of the experiment was laid out as a simple lattice design under two moisture regimes (non-stress and stress conditions) during the off-season (December 2016-March 2017). Each genotype was planted on two rows, each 3m long with inter-row spacing of 0.3m. Seeds were drilled on the rows manually at a rate of 100 kg/ ha. Plants were fertilized with phosphorus 50 kg/ ha in the form of DAP and nitrogen 100kg /ha in the form of Urea. The DAP fertilizer was applied once at sowing time whereas the Urea was applied in split (half at sowing time and the remaining 50% at booting growth stages).

Drought stress regime was started by stopping irrigation at 50% heading stage in order to simulate terminal drought stress. Under both moisture regimes weeds were controlled manually. Data of grain yield harvested from a net plot area of 1.8m^2 were weighed in gram and was then converted into ton $ha^{-1}$for analysis.

Data Analysis

Data of grain yield from the moisture-stressed and non-stressed environments were recorded and drought tolerance indices were calculated according to the formulae presented in (Table1).The Analysis of Variance, Pearson Correlations, Principal Component Analysis (PCA) and Cluster Analysis were carried out using the SAS 9.0 software (SAS Institute. 2002).

Table1. Drought tolerance indices

Drought Tolerance indices	Formula	References
Yield stability index (YSI)	Ysi /Ypi	Bouslama and Schapaugh (1984)
Stress susceptibility index (SSI)	[1-YSI]/SI	Fischer and Maurer (1978)
Yield index (YI)	Ysi/Ys	Meysam and Farshadfar (2015)
Stress tolerance index (STI)	(Ypi x Ysi)/Yp2	Fernandez (1992)
Geometric mean productivity (GMP)	$\sqrt{(\text{Ypi x Ysi})}$	Fernandez (1992)
Tolerance index (TOL)	Ypi – Ysi	Rosielle and Hamblin (1981)
Mean productivity (MP)	(Ypi + Ysi)/2	Rosielle and Hamblin (1981)

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

Results and Discussion

Yield Response

The results of the analysis of variance for grain yield indicated the presence of a considerable genotypic variation under non-stressed and stressed conditions (Table2), thereby suggesting the possibility of selecting better-performing genotypes under non-stress and stress environments. Similar findings were reported by (Anwar *et al*. 2011; Drikvand *et al*. 2012; Habtamu *et al*. 2016). The mean seed yield under non-stressed conditions was 5.03 t/ha compared to 3.49 t/ha in the stressed conditions. The result showed that drought stress significantly reduced the grain yield by 30.6%. These results are supported by those of Darzi-Ramandi *et al. (*2016) and Sahar *et al*. (2016) who found 49.9% and 42% grain yield reduction in bread wheat, caused by moisture stress respectively.

Data concerning yield (Yp and Ys) and indices are given in (Table 3). Genotypes (147 ,100,137,7 and 18) had high grain yield of7.35,7.01,6.64,6.68 and 6.62 t ha^{-1}under non-stress and 6.87,6.37,6.07,5.77 and 6.26 t ha^{-1} , under stress condition respectively. The yield under water-stressed conditions (Ys) had a very weak association with the yield under non-stressed conditions (Yp), indicating that high potential yield under non-stress conditions does not necessarily result in improved yield in a stressed condition. For example, the genotypes 81, 83, 95,161,222,232 and 126 produced the highest yield under non-stressed conditions but failed to produce high yields in the stressed environment.

Therefore, indirect selection for such conditions based on the results of optimum conditions will not be efficient.

According to mean productivity (MP), geometric mean productivity (GMP) and stress tolerance index (STI) genotypes 147, 100, 7, 18 and 137 were the most droughts tolerant, whereas genotypes 78, 182, 60, 97and 227 were the most sensitive genotypes. This suggested that these three indices are comparable for selecting the genotypes. The lowest tolerance index (TOL) value was found in Genotypes 10, 38 and 176, indicating these genotypes had a lower grain yield reduction in stressed condition. According to stress susceptibility index (SSI), genotypes 10, 38 and 176 had the highest values, and were considered as genotypes with high drought susceptibility and poor yield stability in both stress and non-stress conditions. With regard to yield stability index (YSI) genotypes 10, 38, 42 and 176 were the most stable under stress and non-stress conditions. On the other hand, genotypes 118, 81,126 and 232 were the least stable genotypes. According to yield index (YI) genotypes 147, 100, 18 and 137 were the most tolerant and genotypes 67,166,250 and 211were susceptible genotypes.

Table 2. Analysis of genotypic variance for grain yield under moisture-stressed and non-stressed environments

Source of variation	Non stressed environment		Stressed environment	
	df	MS	df	MS
Replication	1	23.92	1	2.9161
Genotype	255	1.3662**	255	1.7462**
Block (adj)	255	0.1057	255	0.1700
Intra block error	225	0.09227	225	0.1575
CV	6.03		11.36	
Mean	5.03		3.49	

Table 3.Mean yields (t ha[-1]) and yield-based drought tolerance indices of 256 bread wheat genotypes under non-stress (Yp) and stress (Ys) conditions.

Geno	Yp	Ys	MP	TOR	YSI	SSI	YI	STI	GMP	Geno	Yp	Ys	MP	TOL	YSI	SSI	YI	STI	GMP
1	5.28	3.88	4.58	1.40	0.74	0.87	1.11	0.81	4.53	33	5.46	4.26	4.86	1.21	0.78	0.72	1.22	0.92	4.82
2	5.02	3.76	4.39	1.27	0.75	0.82	1.08	0.75	4.34	34	5.05	3.46	4.26	1.59	0.68	1.03	0.99	0.69	4.18
3	5.40	3.95	4.68	1.45	0.73	0.88	1.13	0.84	4.62	35	4.39	2.63	3.51	1.76	0.60	1.31	0.75	0.46	3.39
4	5.04	3.80	4.42	1.24	0.75	0.80	1.09	0.76	4.37	36	6.23	4.29	5.26	1.95	0.69	1.02	1.23	1.06	5.17
5	4.23	3.56	3.89	0.68	0.84	0.52	1.02	0.59	3.88	37	5.37	3.93	4.65	1.44	0.73	0.88	1.13	0.83	4.59
6	4.89	3.68	4.29	1.21	0.75	0.81	1.05	0.71	4.24	38	5.42	4.95	5.18	0.47	0.91	0.28	1.42	1.06	5.18
7	6.68	5.42	6.05	1.26	0.81	0.61	1.55	1.43	6.02	39	3.83	2.89	3.36	0.94	0.75	0.80	0.83	0.44	3.33
8	4.88	3.82	4.35	1.07	0.78	0.72	1.09	0.74	4.32	40	3.79	3.26	3.52	0.53	0.86	0.45	0.93	0.49	3.51
9	5.17	3.33	4.25	1.84	0.64	1.16	0.95	0.68	4.14	41	5.79	4.16	4.98	1.63	0.72	0.92	1.19	0.95	4.91
10	5.61	5.09	5.35	0.52	0.91	0.30	1.46	1.13	5.34	42	3.90	3.44	3.67	0.46	0.88	0.38	0.99	0.53	3.66
11	6.35	5.12	5.73	1.23	0.81	0.63	1.47	1.28	5.70	43	5.63	4.49	5.06	1.14	0.80	0.66	1.29	1.00	5.03
12	4.92	3.48	4.20	1.45	0.71	0.96	1.00	0.68	4.14	44	5.77	4.72	5.25	1.05	0.82	0.60	1.35	1.08	5.22
13	5.32	3.79	4.56	1.53	0.71	0.94	1.09	0.80	4.49	45	5.37	2.80	4.08	2.57	0.52	1.57	0.80	0.59	3.87
14	5.01	4.00	4.50	1.01	0.80	0.66	1.15	0.79	4.48	46	5.17	3.48	4.32	1.69	0.67	1.07	1.00	0.71	4.24
15	5.08	3.09	4.08	2.00	0.61	1.28	0.88	0.62	3.96	47	5.31	4.24	4.77	1.07	0.80	0.66	1.21	0.89	4.74
16	6.01	4.34	5.17	1.67	0.72	0.91	1.24	1.03	5.11	48	5.24	4.05	4.64	1.19	0.77	0.74	1.16	0.84	4.60
17	5.60	4.47	5.03	1.13	0.80	0.66	1.28	0.99	5.00	49	5.64	4.11	4.87	1.53	0.73	0.89	1.18	0.91	4.81
18	6.62	5.91	6.26	0.72	0.89	0.35	1.69	1.55	6.25	50	4.64	2.96	3.80	1.69	0.64	1.19	0.85	0.54	3.70
19	5.18	2.92	4.05	2.26	0.56	1.42	0.84	0.60	3.89	51	5.47	4.08	4.77	1.39	0.75	0.83	1.17	0.88	4.72
20	5.78	4.15	4.96	1.63	0.72	0.92	1.19	0.95	4.90	52	4.81	3.37	4.09	1.44	0.70	0.98	0.97	0.64	4.03
21	4.41	3.23	3.82	1.18	0.73	0.87	0.93	0.56	3.77	53	4.23	2.62	3.42	1.61	0.62	1.25	0.75	0.44	3.32
22	4.96	3.29	4.12	1.68	0.66	1.10	0.94	0.64	4.04	54	4.95	2.60	3.77	2.35	0.53	1.55	0.74	0.51	3.59
23	4.77	3.15	3.96	1.62	0.66	1.11	0.90	0.59	3.88	55	5.62	4.28	4.95	1.34	0.76	0.78	1.23	0.95	4.90
24	5.35	3.22	4.29	2.13	0.60	1.30	0.92	0.68	4.15	56	5.62	4.03	4.82	1.59	0.72	0.93	1.15	0.89	4.76
25	3.39	2.64	3.01	0.75	0.78	0.72	0.76	0.35	2.99	57	6.23	5.19	5.71	1.04	0.83	0.55	1.49	1.28	5.69
26	5.69	3.84	4.76	1.86	0.67	1.07	1.10	0.86	4.67	58	4.77	3.52	4.14	1.26	0.74	0.86	1.01	0.66	4.09
27	4.86	2.71	3.78	2.15	0.56	1.45	0.78	0.52	3.63	59	5.27	2.99	4.13	2.28	0.57	1.42	0.86	0.62	3.97
28	5.47	4.56	5.02	0.91	0.83	0.54	1.31	0.99	5.00	60	3.28	1.65	2.46	1.64	0.50	1.63	0.47	0.21	2.32
29	2.97	1.98	2.47	0.99	0.67	1.09	0.57	0.23	2.42	61	4.76	2.29	3.52	2.48	0.48	1.70	0.65	0.43	3.30
30	5.80	4.25	5.02	1.55	0.73	0.87	1.22	0.97	4.96	62	6.01	4.88	5.44	1.13	0.81	0.62	1.40	1.16	5.41
31	4.84	3.40	4.12	1.44	0.70	0.97	0.97	0.65	4.06	63	5.78	4.46	5.12	1.33	0.77	0.75	1.28	1.02	5.08
32	4.78	2.73	3.75	2.06	0.57	1.40	0.78	0.52	3.61	64	4.99	3.73	4.36	1.26	0.75	0.83	1.07	0.74	4.31

Table 3.Contiued

Geno	Yp	Ys	MP	TOR	YSI	SSI	YI	STI	GMP	Geno	Yp	Ys	MP	TOL	YSI	SSI	YI	STI	GMP
65	3.62	2.31	2.97	1.31	0.64	1.18	0.66	0.33	2.89	98	5.50	4.30	4.90	1.20	0.78	0.71	1.23	0.94	4.86
66	3.48	2.47	2.97	1.02	0.71	0.96	0.71	0.34	2.93	99	5.29	3.75	4.52	1.54	0.71	0.95	1.07	0.78	4.46
67	3.68	1.69	2.68	1.99	0.80	0.65	1.04	0.65	4.06	100	7.01	6.02	6.51	0.99	0.86	0.46	1.72	1.67	6.49
68	4.91	3.53	4.22	1.39	0.68	1.05	0.91	0.58	3.84	101	6.76	4.88	5.82	1.88	0.72	0.91	1.40	1.30	5.74
69	4.53	3.64	4.08	0.90	0.75	0.82	1.11	0.80	4.49	102	5.31	3.84	4.57	1.48	0.72	0.91	1.10	0.81	4.51
70	4.67	3.17	3.92	1.50	0.67	1.08	1.06	0.81	4.53	103	5.50	3.80	4.65	1.71	0.69	1.01	1.09	0.83	4.57
71	5.18	3.89	4.53	1.30	0.80	0.65	1.09	0.72	4.27	104	5.64	4.57	5.10	1.08	0.81	0.62	1.31	1.02	5.07
72	5.55	3.71	4.63	1.84	0.72	0.92	1.15	0.88	4.72	105	4.92	3.46	4.19	1.46	0.70	0.97	0.99	0.67	4.12
73	4.76	3.82	4.29	0.94	0.65	1.15	0.69	0.35	2.98	106	5.53	3.37	4.45	2.16	0.61	1.27	0.97	0.74	4.32
74	5.56	4.00	4.78	1.56	0.53	1.54	0.62	0.35	2.98	107	4.62	3.68	4.15	0.94	0.80	0.66	1.05	0.67	4.12
75	3.71	2.40	3.05	1.31	0.81	0.63	1.12	0.75	4.34	108	5.47	4.32	4.89	1.15	0.79	0.69	1.24	0.93	4.86
76	4.10	2.17	3.14	1.93	0.63	1.21	0.52	0.21	2.29	109	6.10	5.13	5.62	0.97	0.84	0.52	1.47	1.24	5.60
77	4.83	3.91	4.37	0.93	0.48	1.69	0.57	0.33	2.88	110	5.58	4.97	5.27	0.61	0.89	0.35	1.42	1.10	5.26
78	2.89	1.82	2.35	1.07	0.75	0.82	1.17	0.88	4.72	111	5.94	4.66	5.30	1.29	0.78	0.71	1.33	1.09	5.26
79	4.15	2.00	3.08	2.15	0.40	1.94	0.54	0.34	2.95	112	5.56	4.29	4.93	1.27	0.77	0.75	1.23	0.94	4.89
80	5.45	4.08	4.77	1.37	0.72	0.93	1.10	0.82	4.54	113	5.07	3.02	4.04	2.05	0.60	1.32	0.87	0.60	3.91
81	4.63	1.88	3.25	2.76	0.59	1.35	0.72	0.42	3.27	114	5.44	3.61	4.52	1.83	0.66	1.10	1.03	0.78	4.43
82	5.37	3.85	4.61	1.52	0.67	1.06	1.11	0.87	4.70	115	5.11	3.19	4.15	1.93	0.62	1.23	0.91	0.64	4.04
83	4.27	2.51	3.39	1.77	0.79	0.70	1.11	0.75	4.36	116	5.11	2.56	3.83	2.56	0.50	1.63	0.73	0.52	3.61
84	5.72	3.86	4.79	1.86	0.77	0.76	1.17	0.86	4.67	117	5.59	3.66	4.62	1.93	0.66	1.13	1.05	0.81	4.52
85	4.92	3.86	4.39	1.06	0.56	1.44	0.93	0.75	4.34	118	4.93	1.98	3.45	2.95	0.40	1.96	0.57	0.38	3.12
86	5.32	4.09	4.71	1.23	0.72	0.91	1.12	0.84	4.62	119	5.32	4.00	4.66	1.32	0.75	0.81	1.14	0.84	4.61
87	5.80	3.25	4.53	2.55	0.73	0.87	1.18	0.91	4.79	120	5.19	3.55	4.37	1.64	0.68	1.03	1.02	0.73	4.29
88	5.44	3.93	4.68	1.51	0.66	1.11	0.82	0.49	3.53	121	5.58	3.91	4.74	1.68	0.70	0.98	1.12	0.86	4.67
89	5.59	4.11	4.85	1.49	0.74	0.85	1.11	0.80	4.49	122	5.15	3.55	4.35	1.60	0.69	1.02	1.02	0.72	4.27
90	4.34	2.87	3.60	1.47	0.77	0.74	0.94	0.55	3.72	123	5.55	4.15	4.85	1.40	0.75	0.83	1.19	0.91	4.80
91	5.22	3.86	4.54	1.36	0.69	1.02	1.01	0.72	4.26	124	5.25	3.03	4.14	2.22	0.58	1.38	0.87	0.63	3.98
92	4.23	3.27	3.75	0.96	0.62	1.25	0.57	0.26	2.55	125	4.62	2.29	3.45	2.33	0.50	1.65	0.66	0.42	3.25
93	5.13	3.54	4.33	1.59	0.50	1.63	0.73	0.51	3.59	126	5.39	2.33	3.86	3.06	0.43	1.85	0.67	0.50	3.54
94	3.25	2.00	2.62	1.25	0.48	1.69	0.61	0.37	3.05	127	5.03	3.25	4.14	1.78	0.65	1.16	0.93	0.65	4.04
95	5.08	2.54	3.81	2.54	0.64	1.17	0.56	0.23	2.42	128	5.41	3.78	4.59	1.64	0.70	0.99	1.08	0.81	4.52
96	4.39	2.12	3.25	2.27	0.78	0.71	1.23	0.94	4.86	129	5.47	3.54	4.50	1.93	0.65	1.15	1.01	0.76	4.40
97	3.02	1.94	2.48	1.08	0.71	0.95	1.07	0.78	4.46	130	5.26	3.69	4.47	1.58	0.70	0.98	1.06	0.77	4.40

Table 3.Contiued

Geno	Yp	Ys	MP	TOL	YSI	SSI	YI	STI	GMP	Geno	Yp	Ys	MP	TOL	YSI	SSI	YI	STI	GMP
131	3.12	1.92	2.52	1.21	0.61	1.26	0.55	0.24	2.44	163	4.96	3.18	4.07	1.78	0.64	1.17	0.91	0.62	3.97
132	5.55	3.85	4.70	1.71	0.69	1.01	1.10	0.84	4.62	164	5.91	4.03	4.97	1.88	0.68	1.04	1.15	0.94	4.88
133	5.91	3.53	4.72	2.38	0.60	1.32	1.01	0.82	4.57	165	4.77	3.99	4.38	0.78	0.84	0.54	1.14	0.75	4.36
134	5.90	4.66	5.28	1.24	0.79	0.69	1.34	1.09	5.24	166	3.99	1.69	2.84	2.30	0.42	1.88	0.48	0.27	2.60
135	4.34	3.22	3.78	1.12	0.74	0.85	0.92	0.55	3.74	167	3.63	2.76	3.19	0.87	0.76	0.78	0.79	0.40	3.16
136	5.54	4.27	4.90	1.27	0.77	0.75	1.22	0.93	4.86	168	4.07	2.84	3.45	1.23	0.70	0.99	0.81	0.46	3.40
135	4.34	3.22	3.78	1.12	0.74	0.85	0.92	0.55	3.74	169	4.27	3.31	3.79	0.96	0.78	0.73	0.95	0.56	3.76
136	5.54	4.27	4.90	1.27	0.77	0.75	1.22	0.93	4.86	170	5.89	4.09	4.99	1.80	0.69	1.00	1.17	0.95	4.91
137	6.64	5.72	6.18	0.92	0.86	0.45	1.64	1.50	6.16	171	5.91	4.21	5.06	1.70	0.71	0.94	1.20	0.98	4.98
138	5.85	4.15	5.00	1.70	0.71	0.95	1.19	0.96	4.92	172	5.31	3.98	4.64	1.33	0.75	0.82	1.14	0.83	4.59
139	5.68	3.80	4.74	1.88	0.67	1.08	1.09	0.85	4.65	173	5.65	4.37	5.01	1.28	0.77	0.74	1.25	0.98	4.97
140	5.62	4.97	5.30	0.65	0.88	0.38	1.42	1.10	5.29	174	5.10	3.51	4.31	1.59	0.69	1.02	1.01	0.71	4.23
141	4.89	3.96	4.42	0.93	0.81	0.62	1.13	0.77	4.40	175	5.42	2.82	4.12	2.60	0.52	1.57	0.81	0.60	3.91
142	5.73	3.04	4.38	2.69	0.53	1.53	0.87	0.69	4.17	176	6.05	5.32	5.68	0.73	0.88	0.39	1.52	1.27	5.67
143	5.84	3.84	4.84	2.00	0.66	1.12	1.10	0.89	4.73	177	6.37	5.51	5.94	0.87	0.86	0.44	1.58	1.39	5.92
144	5.28	3.57	4.43	1.71	0.68	1.06	1.02	0.75	4.34	178	5.70	4.23	4.96	1.47	0.74	0.84	1.21	0.95	4.91
145	5.70	4.48	5.09	1.22	0.79	0.70	1.28	1.01	5.05	179	5.31	3.96	4.63	1.36	0.74	0.83	1.13	0.83	4.58
146	6.21	5.20	5.70	1.01	0.84	0.53	1.49	1.28	5.68	180	5.95	4.43	5.19	1.52	0.74	0.84	1.27	1.04	5.13
147	7.35	6.52	6.93	0.84	0.89	0.37	1.87	1.89	6.92	181	5.09	3.74	4.42	1.35	0.73	0.87	1.07	0.75	4.36
148	6.05	4.23	5.14	1.82	0.70	0.99	1.21	1.01	5.06	182	2.84	1.85	2.34	1.00	0.65	1.15	0.53	0.21	2.29
149	5.21	3.60	4.41	1.61	0.69	1.01	1.03	0.74	4.33	183	4.75	2.19	3.47	2.56	0.46	1.76	0.63	0.41	3.22
150	5.03	3.96	4.49	1.07	0.79	0.69	1.13	0.79	4.46	184	4.80	3.16	3.98	1.64	0.66	1.12	0.90	0.60	3.89
151	5.53	4.21	4.87	1.32	0.76	0.78	1.21	0.92	4.83	185	6.11	4.86	5.49	1.25	0.80	0.67	1.39	1.17	5.45
152	5.66	4.31	4.98	1.35	0.76	0.78	1.23	0.96	4.94	186	3.66	3.02	3.34	0.64	0.82	0.57	0.86	0.44	3.32
153	5.38	4.07	4.72	1.31	0.76	0.80	1.16	0.86	4.68	187	4.05	3.07	3.56	0.98	0.76	0.79	0.88	0.49	3.52
154	5.77	4.33	5.05	1.44	0.75	0.82	1.24	0.99	5.00	188	4.93	2.74	3.83	2.19	0.56	1.45	0.78	0.53	3.67
155	5.36	4.22	4.79	1.14	0.79	0.70	1.21	0.89	4.76	189	4.01	3.41	3.71	0.60	0.85	0.49	0.98	0.54	3.70
156	4.67	3.62	4.15	1.05	0.77	0.74	1.04	0.67	4.11	190	3.87	2.26	3.06	1.62	0.58	1.36	0.65	0.35	2.96
157	5.18	2.95	4.06	2.24	0.57	1.41	0.84	0.60	3.91	191	4.64	3.73	4.18	0.91	0.80	0.64	1.07	0.68	4.16
158	4.90	3.94	4.42	0.97	0.80	0.64	1.13	0.76	4.39	192	5.09	2.49	3.79	2.61	0.49	1.67	0.71	0.50	3.56
159	4.34	3.40	3.87	0.94	0.78	0.70	0.97	0.58	3.84	193	3.68	2.68	3.18	1.00	0.73	0.89	0.77	0.39	3.14
160	4.71	3.25	3.98	1.46	0.69	1.02	0.93	0.60	3.91	194	3.72	2.10	2.91	1.62	0.56	1.42	0.60	0.31	2.79
161	5.54	2.61	4.07	2.93	0.47	1.73	0.75	0.57	3.80	195	4.01	1.93	2.97	2.08	0.48	1.69	0.55	0.31	2.78
162	5.70	3.55	4.62	2.15	0.62	1.23	1.02	0.80	4.50	196	3.68	2.15	2.91	1.53	0.58	1.36	0.62	0.31	2.81

Table 3.Contiued

Geno	Yp	Ys	MP	TOR	YSI	SSI	YI	STI	GMP	Geno	Yp	Ys	MP	TOL	YSI	SSI	YI	STI	GMP
197	4.28	2.92	3.60	1.36	0.68	1.04	0.84	0.49	3.53	228	4.44	2.60	3.52	1.84	0.59	1.36	0.74	0.46	3.40
198	4.89	2.48	3.68	2.42	0.51	1.61	0.71	0.48	3.48	229	5.74	3.23	4.49	2.51	0.56	1.43	0.93	0.73	4.31
199	4.21	2.86	3.54	1.35	0.68	1.05	0.82	0.48	3.47	230	6.27	5.53	5.90	0.75	0.88	0.39	1.58	1.37	5.89
200	4.36	2.37	3.36	1.99	0.54	1.49	0.68	0.41	3.21	231	4.23	3.49	3.86	0.75	0.82	0.58	1.00	0.58	3.84
201	4.32	2.24	3.28	2.08	0.52	1.58	0.64	0.38	3.11	232	5.17	2.17	3.67	3.00	0.42	1.89	0.62	0.44	3.35
202	5.73	4.59	5.16	1.14	0.80	0.65	1.32	1.04	5.13	233	4.20	3.57	3.88	0.64	0.85	0.50	1.02	0.59	3.87
203	4.56	2.90	3.73	1.66	0.64	1.19	0.83	0.52	3.63	234	6.32	5.41	5.86	0.91	0.86	0.47	1.55	1.35	5.85
204	3.01	2.35	2.68	0.66	0.78	0.72	0.67	0.28	2.66	235	5.69	4.50	5.09	1.20	0.79	0.69	1.29	1.01	5.06
205	5.58	3.95	4.76	1.64	0.71	0.96	1.13	0.87	4.69	236	3.59	1.93	2.76	1.66	0.54	1.51	0.55	0.27	2.63
206	3.83	2.29	3.06	1.55	0.60	1.32	0.65	0.35	2.96	237	5.36	2.99	4.18	2.37	0.56	1.45	0.86	0.63	4.00
207	4.29	2.16	3.23	2.13	0.50	1.62	0.62	0.37	3.04	238	4.71	2.61	3.66	2.10	0.55	1.45	0.75	0.49	3.50
208	4.38	2.59	3.48	1.80	0.59	1.34	0.74	0.45	3.37	239	5.43	2.84	4.13	2.59	0.52	1.56	0.81	0.61	3.92
209	5.46	3.69	4.57	1.78	0.67	1.06	1.06	0.80	4.49	240	5.80	4.58	5.19	1.23	0.79	0.69	1.31	1.05	5.15
210	5.17	3.40	4.29	1.77	0.66	1.12	0.97	0.70	4.19	241	5.63	4.45	5.04	1.19	0.79	0.69	1.27	0.99	5.00
211	3.68	1.75	2.72	1.93	0.47	1.71	0.50	0.25	2.54	242	5.83	4.27	5.05	1.56	0.73	0.88	1.22	0.98	4.99
212	5.47	4.01	4.74	1.47	0.73	0.88	1.15	0.87	4.68	243	5.11	4.25	4.68	0.86	0.83	0.55	1.22	0.86	4.66
213	5.25	4.11	4.68	1.14	0.78	0.71	1.18	0.85	4.65	244	5.62	4.07	4.84	1.56	0.72	0.91	1.16	0.90	4.78
214	4.62	3.04	3.83	1.58	0.66	1.12	0.87	0.56	3.75	245	4.56	3.29	3.92	1.28	0.72	0.91	0.94	0.59	3.87
215	5.81	3.40	4.60	2.42	0.58	1.36	0.97	0.78	4.44	246	4.28	2.50	3.39	1.78	0.58	1.36	0.72	0.42	3.27
216	3.48	2.59	3.03	0.90	0.74	0.84	0.74	0.36	3.00	247	5.91	3.56	4.73	2.35	0.60	1.30	1.02	0.83	4.59
217	3.56	2.00	2.78	1.56	0.56	1.43	0.57	0.28	2.66	248	4.94	3.57	4.25	1.38	0.72	0.91	1.02	0.70	4.20
218	4.17	3.04	3.61	1.13	0.73	0.89	0.87	0.50	3.56	249	3.82	2.33	3.07	1.50	0.61	1.28	0.67	0.35	2.98
219	4.75	3.36	4.05	1.39	0.71	0.96	0.96	0.63	3.99	250	4.10	1.73	2.91	2.37	0.42	1.89	0.49	0.28	2.66
220	3.77	2.32	3.05	1.45	0.61	1.26	0.66	0.35	2.96	251	5.00	2.28	3.64	2.72	0.46	1.78	0.65	0.45	3.38
221	5.88	3.47	4.67	2.42	0.59	1.34	0.99	0.81	4.51	252	5.45	4.05	4.75	1.41	0.74	0.84	1.16	0.87	4.70
222	5.64	2.78	4.21	2.86	0.49	1.65	0.80	0.62	3.96	253	5.61	3.66	4.63	1.95	0.65	1.14	1.05	0.81	4.53
223	4.19	2.16	3.17	2.03	0.52	1.58	0.62	0.36	3.01	254	3.68	1.78	2.73	1.90	0.48	1.69	0.51	0.26	2.55
224	5.55	3.45	4.50	2.10	0.62	1.24	0.99	0.76	4.37	255	4.82	2.75	3.78	2.07	0.57	1.40	0.79	0.52	3.64
225	4.17	3.03	3.60	1.14	0.73	0.89	0.87	0.50	3.55	256	5.34	2.97	4.16	2.37	0.56	1.45	0.85	0.63	3.98
226	6.30	4.92	5.61	1.38	0.78	0.72	1.41	1.22	5.57										
227	2.99	1.99	2.49	1.01	0.66	1.10	0.57	0.23	2.44										

Correlations between Drought Tolerance Indices

Selection based on a combination of indices may provide a more suitable criterion for improving drought tolerance of wheat, and the study of correlation coefficients is useful in finding the degree of overall linear association between any two attributes (Talebi *et al*., 2009). The Pearson correlation coefficients of grain yield under the non-stressed and moisture-stressed conditions with drought-tolerance indices (Table 4) showed grain yield in the stressed environment (Ys) was significantly and positively correlated with grain yield in the non- stress environment(Yp), mean productivity (MP), geometric mean productivity (GMP), stress tolerance index (STI), yield stability index (YSI) and yield index (YI), while significantly and negatively correlated with stress susceptibility index (SSI) and tolerance index (TOL). Similarly, grain yield in the non-stressed environment (Yp) was significantly and positively correlated with grain yield in the stressed environment (Ys), mean productivity (MP), geometric mean productivity (GMP), yield stability index (YSI), yield index (YI) and stress tolerance index (STI), but significantly and negatively correlated with stress susceptibility index (SSI).

There were significant and strong positive associations of grain yield under stressed and non-stressed conditions with stress tolerance index (STI) (r = 0.97 and r = 0.90), mean productivity (MP) (r = 0.96 and r =0.95), geometric mean productivity (GMP) (r =0.98 and r =0.92) and yield index (YI) (r =1.00 and r =0.82), respectively. Indicating that the four indices were more effective for selecting better grain-yielding genotypes under both moisture-stressed and non-stressed conditions. Similar results were observed by Ezatollah et *al* (2012), Farshadfar *et al.* (2013), Darzi-Ramandi *et al.* (2016) and Sardouie-Nasab *et al.* (2015) for the four induces. The correlation among the indices of stress tolerance index (STI), mean productivity (MP), geometric mean productivity (GMP), yield stability index (YSI) and yield index (YI) were positively highly significant, showing high similarity among these indices for selecting the best genotype. Results of correlation analysis also exhibited positive and significant relationship between tolerance index (TOL) and stress susceptibility index (SSI). The highest correlation (r^2 = 1.00) was observed between mean grain yield of genotypes under non-stress (Ys) and yield index (YI). These results of this study were in agreement with the results of (Ezatollah et *al.,* 2012; Tauqeer *et al*., 2013; Darzi-Ramandi *et al.,* 2016).

In conclusion the positive and significant correlations of grain yield in the stressed (Ys) and grain yield in the non-stressed condition (Yp) with stress tolerance index (STI), mean productivity (MP), geometric mean productivity (GMP), yield stability index (YSI) and yield index (YI) indicated that these indices were the best predictors of yield under moisture stressed and non-stressed conditions. In line with this result, (Tauqeer *et al*., 2013) reported positive and significant correlations of grain yield in the stressed (Ys) and non-stressed conditions (Yp) with stress tolerance index (STI), mean productivity (MP) and geometric mean productivity (GMP). Whereas the genotypes with high values of tolerance index (TOL) and stress susceptibility index (SSI) were able to produce high yield only in the non-stressed condition. Generally, drought significantly reduced the yield of some of the genotypes while some of the genotypes were tolerant to drought, indicating the existence of genetic variability for drought tolerance among the genotypes we have studied. Therefore, breeders can select suitable genotypes under water-stressed conditions and compare their performance under non-stressed conditions using drought tolerance indices as a means to combine information on performance under both water regimes.

Table 4. Pearson's correlation coefficients between grain yield of 256 bread wheat genotypes under moisture-stressed and non-stressed conditions and yield-based drought tolerance indices.

	Yp	Ys	MP	TOL	YSI	GMP	SSI	YI	STI
Yp	1.00**								
Ys	0.82 **	1.00							
MP	0.95 **	0.96 **	1.00						
TOL	0.11ns	-0.48**	-0.22*	1.00					
YSI	0.33**	0.80 **	0.61 **	-0.89**	1.00				
GMP	0.92 **	0.98 **	1.00 **	-0.28**	0.55 **	1.00			
SSI	-0.33**	-0.80**	-0.61**	0.89**	-1.00**	-0.55**	1.00		
YI	0.82 **	1.00 **	0.96 **	-0.48**	0.80 **	0.98 **	-0.80**		
STI	0.90 **	0.97**	0.99 **	-0.31**	0.56 **	0.99 **	-0.66**	0.97 **	1.00

* $P \leq 0.05$, ** $P \leq 0.01$, ns = non-significant

Principal Component Analysis

Principal components of the drought- tolerance indices and grain yield under moisture-stressed and non-stressed conditions of the 256 bread wheat genotypes are presented in (Table 5).Principal component analysis was performed to assess the relationships between all attributes to identify superior genotypes for both water-stressed and non-stressed conditions .The Principal Components analysis explained 99.5 % of the total variation considering the first two PCs. PC1 alone explained 78.08% of the total variation with high loading due to grain yield in the stress (Ys), yield index (YI), stress tolerance index (STI), geometric mean productivity (GMP) and mean productivity (MP). The genotypes which have a high value of first component (PC1) are expected to have a high yield under both stress and non-stressed conditions. The PC2 explained 21.43% % of the total yield variation with high loading due to tolerance index (TOL), grain yield under non-stress (Yp), stress susceptibility index (SSI) and yield stability index (YSI).Therefore, PC1 and PC2 were named grain yield potential and drought stress susceptibility, respectively.

Based on this criterion, stable genotypes possessed greater PC1 but lower PC2 values and contrariwise (Kaya *et al*., 2006). wheat genotypes with higher PC1 and lower PC2 values had high grain yields (stable genotypes) and genotypes with lower PC1 and higher PC2 scores had low grain yield (unstable genotypes). Drikvand *et al*. (2012) reported that 99% of the variation when using five drought tolerance indices was explained by two PCs only. They pinpointed the high association of stress tolerance index (STI), mean productivity (MP) and geometric mean productivity (GMP) with grain yield under both conditions. Nouraein *et al*. (2013) also reported that two PCs explained 99% of the variation of eight drought tolerance indices of wheat recombinant inbred lines evaluated under moisture-stressed and non-stressed conditions.

In addition to correlation analysis, a biplot based on principal component analysis was constructed to identify superior genotypes for both water-stressed and non-stressed environments. The results from the PCA are summarized in a biplot graph (Figure 1). Accordingly, selection for high PC1 loading leads to selection of genotypes with high grain yield in both stressed and non-stressed environments, whereas selection for low PC2 loading favours selection of genotypes with lower grain yield reduction due to moisture stress .The favours for low PC2 loading is because of its high association with stress susceptibility index (SSI) and tolerance induce (TOL), in which a lower value is preferred for the lower sensitivity to moisture stress. Genotypes 147 and 100 in Quadrant-I had the highest PC1 loading for their high grain yield under moisture-stressed and non-stressed conditions and intermediate PC2 loading for their low grain yield reduction due to moisture-stress .Genotypes in Quadrants II and III had low to intermediate grain yield under moisture-stressed and non-stressed conditions with low grain yield reduction caused by moisture stress. Genotypes 126,161,232 and 222 in Quadrant IV with low PC1 and high PC2 values were identified as susceptible genotypes. Similarly, Darzi-Ramandi *et al.* (2016) used a biplot analysis to discriminate high yielding bread wheat genotypes.

Table 5. Principal component analysis for grain yield of 256 bread wheat genotypes under moisture-stressed and non-stressed conditions and yield-based drought tolerance indices

Drought tolerance index	Principal component 1	Principal component 2
Grain yield under non-stressed environments (Yp)	0.30	0.44
Grain yield under moisture-stressed environment (Y_s)	0.38	0.03
Mean productivity (MP)	0.36	0.23
Tolerance index (TOL)	-0.20	0.61
Grain yield stability index (YSI)	0.31	-0.40
Stress susceptibility index (SSI)	-0.31	0.40
Grain yield index (YI)	0.38	0.03
Stress tolerance index (STI)	0.36	0.17
Geometric mean productivity (GMP)	0.36	0.19
Eigenvalue	7.03	1.93
Percentage of total variation explained	78.08	21.43
Percentage of cumulative variation explained	78.08	99.5

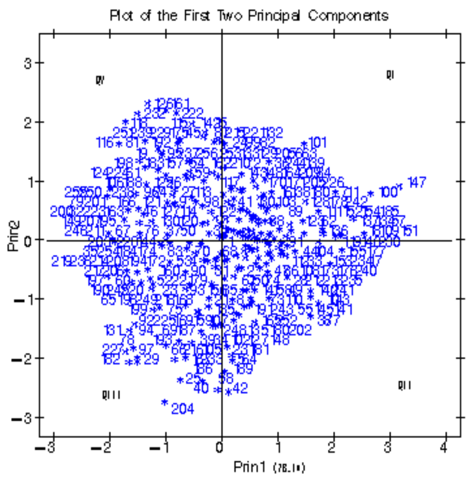

Figure 1: Biplot of principal component 1 (78.08%) and principal component 2 (21.43%) showing the relationship of 256 genotypes for grain yield under moisture-stressed and non-stressed conditions using drought tolerance indices.

Cluster Analysis

Cluster analysis based on drought tolerance indices and grain yield under stressed and non-stressed conditions classified the genotypes into nine clusters (Table 6). Clusters I, II, III, IV, V, VI, VII, VIII and IX consisted of 27.3%, 11.7%, 32.8%, 11.3%, 3.1%, 6.6%, 2.7%, 2.7% and 1.6% of the genotypes, respectively. Genotypes in Clusters VI and IX had high grain yield under both the moisture -stressed and non-stressed conditions and have high value of stress tolerance index (STI), mean productivity (MP), geometric mean productivity (GMP) and yield induces (YI) but the grain yield reduction due to moisture stress was higher in Cluster VI than IX. Cluster VII included genotypes with high grain yield under non-stress (Yp) but low grain yield under stress (Ys) conditions. Genotypes in Cluster V and VIII showed low (grain yield under non-stress (Yp), grain yield under stress (Ys),stress tolerance index (STI), mean productivity (MP) and geometric mean productivity)and high tolerance index (TOR).Thus, the genotypes in cluster V and VIII were identified as drought susceptible genotypes. Whereas genotypes in Clusters I had intermediate grain yield under both the moisture stressed and non-stressed conditions and intermediate value of the drought tolerance indices. Genotypes in cluster II had intermediate grain yield under non-stressed and low yield in stressed condition. The third cluster had moderately tolerant genotypes characterized by high value of grain yield under non-stress (Yp) and intermediate value of yield induces (YI),stress tolerance induces (STI), stress susceptibility induces (SSI), mean productivity (MP) and geometric mean productivity (GMP). Cluster IV consisted susceptible genotypes which have high value of tolerance induce (TOR) and stress tolerance induce (SSI). Similar to the current findings, cluster analysis has enabled researchers to classify genotypes adapted to moisture-stressed and non-stressed conditions in bread wheat (Eivazi *et al*. 2013 and Johari-Pireivatlou 2014),barley (Nazari and Pakniyat, 2010) and safflower (Bahrami *et al*., 2014). In the present study, it was found that statistical methods including correlation between grain yield and indices, biplot analysis, and cluster analysis were identified the same tolerant genotypes and we also observed mean productivity (MP), geometric mean productivity (GMP) and stress tolerance index (STI) are the best indices for selecting drought tolerant lines.

Table 6.Clustering of the 256 bread wheat genotypes using drought tolerance indices

Cluster	No. of genotypes	Genotypes
I	70	218,225,93,122,12,105,23,184,141,158,5,233,31,52,2,64,174,248,92,169,107,191,8,85,14,150,120,149,4,21,135,77,15,113,219,197,199,9,210,70,160,22,127,50,203,181,231,46,163,69,90,34,156,159,214,130,144,42,189,187,73,115,6,58,245,165,168,40,24
II	30	83,246,211,254,35,208,220,249,190,206,228,194,196,201,207,76,223,67,217,236,166,250,65,75,79,195,96,53,200,60
III	84	20,41,51,80,145,235,117,253,119,172,112,136,26,139,3,37,17,43,30,242,252,179,56,244,98,108,30,242,252,179,56,244.98,108,121,205,55,152,49,89,111,134,13,99,241,71,91,84,82,102,33,88,103,132,47,155,138,48,213,86,153,74,164,170,151,212,202,240,106,224,72,209,1,173,114,129,154,104,171,128,123,16,180,143,63,36,148,44,162,28,243
IV	29	175,239,237,256,19,157,95,116,32,255,59,124,45,27,188,192,61,183,54,198,125,238,161,222,232,251,81,118,126
V	8	29,227,78,182,97,94,131,204
VI	17	57,146,110,140,177,234,62,185,109,230,10,38,11,226,176,7,101
VII	7	133,247,87,229,221,215,142
VIII	7	167,193,25,216,66,39,186
IX	4	18,137,100,147
Total	256	

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