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Original article

Assessment of grain yield indices in response to drought stress in wheat (*Triticum aestivum* L.)

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ABSTRACT

Drought stress constricts crop production in the world. Increasing human population and predicted temperature increase owing to global warming will lead ruthless problems for agricultural production in near future. Hence, use of high yielding genotypes having drought tolerance and scrutinize of drought sensitive local cultivars for making them tolerant may be the proficient approaches to cope its detrimental outcomes. The current study was executed during 20015–2016 and 2016–2017 in field using randomized complete block design under factorial arrangements on 50 wheat genotypes for exploring their sensitivity and tolerance against drought. Some of the attributes of grain yield and drought tolerance indices were recorded. Grain yield showed negative correlations with tolerance index (TOL), drought index (DI) and stress susceptibility index (SSI) while positive correlation with mean productivity (MP) and geometric mean productivity (GMP) under drought condition. These findings depicted that tolerant genotypes could be chosen by high MP and GMP values and low SSI and TOL values. Based on the results, genotypes GA-02, Faisalabad-83, 9444, Sehar-06, Pirsabak-04 and Kohistan-97 were more tolerant and recognized as suitable for both normal and drought conditions. Genotypes of Chenab-00, Kohsar-95, Parwaz-94 and Kohenoor-83 confirmed more sensitive due to high grain yield loss under drought stress.

1. Introduction

Wheat (*Triticum aestivum* L.) belongs to family *Poaceae* and is widely cultivated in the majority of the world regions. Wheat is a main staple food, is cultivated on 9.23-million-hectare area with the estimated production of 25.3 million metric tons with 2.74 metric tons/ha grain yield (USDA, 2017). A lot of constrains and challenges are facing in wheat production and yield in Pakistan as well as in the world. The food security is highly focused on obtaining more food to fulfil the needs of burgeoning population which can only be accomplished when the production of cereal

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crops is increased globally (Ahmed and Mustafa, 2017) and the prevention of stored grain commodities from insect losses (Ahmad et al., 2019).

The drought incidence and severity will certainly increase in coming future as a result of global warming that will direct towards a rigorous decline in overall production of food. Predicted temperature increase of 1.5–5.8 °C by 2100 will lead ruthless problems for agricultural production (Ansari et al., 2014; Field, 2012). At the same time progressively increasing human population that might achieve to nine billion in 2050, requires a surge in food supplies. Since desertification swells further by reason of constant trouncing of arable area the condition will be shattering and distressing more in the upcoming days (Solomon, 2007).

Use of high yielding genotypes having drought tolerance is an efficient approach to lessen its damaging effects. With declining resources of water and escalating intensity of drought, loss of yield is a dangerous alarm in these regions. However, attaining drought tolerance exclusively yield depended is complex due to its intricate heritability. Likewise, choosing genotypes having tolerant genes is a tricky task (Mitra, 2001). Alternatively, some statistical parameters as well as drought tolerance indices could be employed to compare the changes in grain yield in normal and drought conditions for the assortment of genotypes of high yields and drought tolerance (Yadav and Bhatnagar, 2001).

An index of tolerance index (TOL) was defined and pioneered by Rosielle and Hamblin (1981) as grain yield difference in normal (Yp) and drought (Ys) conditions which specified that drought sensitive genotypes show low values of this index. The index of mean productivity (MP) also defined by Rosielle and Hamblin (1981) is the average yield under drought stress (Ys) and normal (Yp) conditions. Fischer and Maurer (1978) projected the stress susceptibility index (SSI) explained that genotypes having the values of SSI less than one were tolerant.

Since Pakistan is the hub of wheat origin having plentiful germplasm of wheat. However, the majority of studies have engaged commercial wheat cultivars to study or develop their characters, but having very minute knowledge about drought tolerance of local cultivars. Thus, present research was executed to screen a number of Pakistani wheat germplasm by means of different indices and to select different drought tolerant and sensitive genotypes for further drought controlling programs.

2. Materials and methods

The study was performed in the field conditions at Research Boulevard of Department of Plant Pathology, Bahauddin Zakariya University (BZU) Multan. The experiments were executed in RCBD under factorial arrangements in sandy clay loam soil at BZU. The germplasm of 50 local genotypes/lines of wheat were collected from Gene Pool of lant breeding and genetics (PBG), University of Agriculture, Faisalabad (UAF) and Wheat Research Institute of Ayoub Agriculture Research Institute (AARI) for evaluating their sensitivity and tolerance against drought. Two plots with each 50 wheat genotypes were planted 1st week of December during 2015–16 and 2016–17 Rabi seasons with a density of 260 seeds m^{-2} to find out the drought sensitive and resistant wheat genotypes. Drought conditions were provided by skipping the irrigation at reproductive and grain filling stage of wheat in one plot in comparison of normal plot where no irrigation was skipped. 1000-grains weight (TGW), Productive tillers (PT), biological yield (BY), harvest index (HI), grain yield (GY), percent yield loss and different drought tolerance indices were precisely calculated. The observed data was analysed through software of Statistix 8.1 and means were compared by LSD test at probability level of 5%. Eqs. (1)–(6) were used for the assessment of drought indices, where Ys and Yp are grain yield in drought and normal conditions.

$$SI = 1 - \frac{\bar{Y}_s}{\bar{Y}_p} \quad \text{(Fischer and Maurer, 1978)} \tag{1}$$

$$SSI = \left(1 - \frac{Y_s}{Y_p}\right)/SI \quad \text{(Fischer and Maurer, 1978)} \tag{2}$$

$$TOL = Y_p - Y_s \quad \text{(Rosielle and Hamblin, 1981)} \tag{3}$$

$$MP = (Y_p + Y_s)/2 \quad \text{(Rosielle and Hamblin, 1981)} \tag{4}$$

$$GMP = \sqrt{Y_p \times Y_s} \quad \text{(Fernandez, 1992)} \tag{5}$$

$$DI = \frac{Y_s}{Y_p} \quad \text{(Khakwani et al., 2011)} \tag{6}$$

3. Results and discussion

3.1. Impact of normal and drought conditions on grain yield

Results for grain yield during the 2015–2016 represented that the lowest and highest grain yields in genotypes Punjab-11 (211.7 g m^{-2}) and Millat-11 (475.3 g m^{-2}) under normal conditions. Genotype 9725 also gave significant high grain yield similar to Millat-11. Under stress conditions, 9444 (419.4 g m^{-2}) and Hashim-10 (161.2 g m^{-2}) depicted the highest and lowest yield respectively (Table 1). For the same season, genotypes Hashim-10 and Punjab-11 showed low yield and MH-97 and 9444 showed high yield in both drought and normal conditions. Genotypes Kohsar-95 and Parwaz-94 showed high yield under normal conditions but produced low grain yield in drought conditions. In the 2016–2017 season, the lowest and highest grain yield showed by Punjab-11 (202.4 g m^{-2}) and Millat-11 (465.2 g m^{-2}) in normal conditions, respectively. For the same season under drought conditions, genotypes Kohinoor-83 and Hashim-10 with 461.7 and 155.3 g m^{-2} ranked first and last, respectively.

Based on following grain yield mean comparisons over 2 seasons (Table 2), categorised the wheat genotypes into four groups. The genotypes *viz.* 9725, Millat-11, Inqalab-91, 9444, Lasani-06, Manthar-03, Pirsabak-04, MH-97, Kohistan-97 and Faisalabad-83 expressed less grain yield losses or in other words high yield in both drought and normal conditions. Thus, arid and semi-arid regions are suitable for cultivation of these genotypes. In the second group the genotypes namely Hashim-10 and Punjab-11, Watan-92, GA-02, Faisalabad-85, Shafaq-06 and Aas-02 showed minimum yield in both normal and drought conditions. Chenab-00, Kohsar-95, Parwaz-94 and Kohenoor-83 genotypes of wheat expressed high yield in normal conditions but in drought conditions low yield was the outcome. Genotypes of this group confirmed high yield loss because of drought stress. Similarly, it was also witnessed that genotypes belong to this groups are most sensitive to drought. Likewise, the rest of the genotypes are included in the fourth group. Dorostkar et al. (2015) also reported the same type of four groups or clusters while evaluating and screening of 36 bread wheat genotypes for drought tolerance and sensitivity under normal and different stress regimes.

Grain yield differences pointed out their differential tolerance and drought sensitivity which can be elucidated by loss in grain yield as an index. Chenab-00, Kohsar-95, Parwaz-94 and Kohinoor-83 showed highest grain yield reduction {(30.6% and 31.2%), (30.7% and 31.7%), (31.3% and 32.1%) and (30.4% and 30.8%)} that means these were highly sensitive to drought, while the lowest reduction (less sensitive or resistant) belonged to GA-02, 9444, Faisalabad-83 {(3.8% and 5.6%), (10.5% and 10.6%) and

Table 1
Average yield components of 50 wheat (*Triticum aestivum* L.) genotypes under normal and drought conditions during the 2015–2016 and 2016–2017 growing seasons.

Genotypes	TGW				PT				BY			
	2015/16		2016/17		2015/16		2016/17		2015/16		2016/17	
	N	D	N	D	N	D	N	D	N	D	N	D
Pb-11	34.7	31.2	33.9	30.5	305	290	296	281	657.0	591.3	652.3	567.3
Gomal-08	37.0	34.1	36.3	33.2	334	317	327	311	817.3	735.6	811.7	717.3
Iqbal-00	37.2	35.7	36.8	34.8	345	328	337	319	850.3	765.3	848.7	740.7
Pak 81	38.9	36.2	38.3	35.4	360	342	351	336	894.3	804.9	889.0	793.3
Watan-92	35.9	33.3	35.7	32.9	311	295	304	287	689.3	620.4	684.0	604.7
Saher-06	40.4	37.6	40.2	36.7	374	356	366	347	1177.0	1059.3	1172.0	1031.3
9495	41.8	32.2	40.9	31.5	401	361	392	352	1235.7	1112.1	1227.7	1099.7
Pb-85	41.7	37.1	40.6	36.3	391	367	382	361	1280.7	1152.6	1272.3	1128.7
LU-26	37.8	33.6	36.3	33.1	337	317	327	309	812.7	731.4	805.7	717.7
Moomal-02	41.6	37.0	40.8	36.3	386	363	378	356	1220.0	1098.0	1213.3	1071.0
Kohistan-97	42.3	38.9	42.1	38.4	405	381	397	372	1272.0	1144.8	1265.7	1132.0
Fsd-83	42.0	38.6	40.8	37.9	405	380	396	373	1340.0	1206.0	1331.7	1198.0
Aas-11	38.9	35.8	38.3	34.7	344	323	336	316	973.7	876.3	961.7	849.0
Kohsar-95	41.1	31.3	40.6	30.6	371	330	362	321	1134.3	1020.9	1127.3	999.7
Fsd-08	40.5	36.0	40.0	35.3	373	362	366	356	1211.0	1089.9	1204.7	1064.0
Uqab-00	41.6	37.0	41.0	35.8	391	380	382	371	1251.7	1063.9	1241.0	1035.0
GA-02	37.7	33.5	37.0	32.9	340	330	332	322	919.0	781.2	909.3	756.3
Glaxy-13	38.7	34.4	37.9	33.7	353	343	345	336	1034.3	879.2	1026.7	845.0
Chakwal-50	42.3	39.8	41.6	39.1	410	397	401	390	1168.7	993.4	1159.3	963.0
Bhakhar-02	41.8	39.3	41.2	38.8	401	385	393	377	1271.3	1080.6	1259.7	1054.7
Pbw-222	43.2	40.6	42.3	39.7	425	408	417	401	1309.7	1113.2	1299.0	1094.7
MH-97	44.6	41.9	43.9	41.2	454	436	447	428	1306.7	1110.7	1297.3	1089.7
Fareed-06	42.2	38.8	41.8	38.0	410	394	403	386	1280.7	1088.6	1270.0	1064.7
Shaheen-94	42.6	39.1	41.8	38.1	406	390	398	383	1272.7	1081.8	1263.0	1063.0
Bathoor-08	40.8	37.6	39.9	36.8	383	368	376	359	1186.7	1008.7	1177.3	979.0
Pirsabak-04	44.5	41.0	43.5	40.0	448	430	338	422	1340.0	1139.0	1332.3	1115.7
Fsd-85	36.0	33.1	35.6	32.7	320	307	310	297	700.7	595.6	682.0	570.3
Shafaq-06	36.2	33.3	35.6	32.9	319	306	311	299	697.3	592.7	682.3	570.0
Kohinoor-83	44.8	33.6	43.7	33.3	447	393	439	386	1373.3	1167.3	1360.3	1133.3
Manthar-03	41.1	35.8	40.5	35.0	388	361	378	353	1230.0	1045.5	1218.7	1027.3
Lasani-06	41.3	35.9	40.6	35.5	385	358	377	351	1223.3	1039.8	1212.7	1016.0
9610	38.3	33.3	38.0	32.7	351	326	342	317	1020.3	867.3	1000.7	857.7
SH-02	41.5	36.1	40.7	35.3	409	381	402	373	1273.0	1082.1	1261.3	1066.7
Parsab-08	40.3	32.6	39.7	32.0	383	357	377	348	1216.7	1034.2	1209.0	1017.3
Anmol-91	41.3	33.4	40.7	32.7	386	359	378	351	1208.7	1027.4	1196.7	1003.0
Aas-02	38.3	31.0	37.6	30.2	348	324	341	318	1035.7	828.5	1024.7	816.0
Parwaz-94	41.2	30.9	40.6	30.1	380	330	372	322	1186.0	948.8	1167.7	923.7
9444	44.7	39.3	43.9	38.7	445	419	437	409	1343.3	1229.7	1323.0	1212.3
Inquilab-91	43.7	38.5	43.3	38.0	421	396	412	389	1324.3	1059.5	1315.3	1024.0
Potohar-73	42.3	37.2	41.9	36.5	397	373	389	366	1289.7	1031.7	1271.3	1013.3
Pict-62	42.2	36.7	41.7	36.0	392	369	386	362	1268.7	1014.9	1253.7	988.7
Wafaq-01	38.5	33.5	37.9	32.8	350	329	342	321	1020.3	816.3	998.0	796.7
AARI-11	42.2	36.7	41.5	36.0	401	377	393	369	1281.0	1024.8	1270.0	999.0
NARC-08	40.1	34.9	39.6	34.2	376	353	370	347	1190.0	952.0	1170.3	922.0
Chenab-00	44.6	34.4	43.8	33.8	447	398	439	390	1386.7	1109.3	1365.7	1096.3
Abadghar-93	42.0	39.5	41.8	38.9	392	372	387	366	1277.3	1021.9	1265.0	1002.0
9725	44.6	41.9	43.7	41.2	441	419	431	411	1393.3	1184.3	1368.0	1163.7
SH-95	38.5	36.2	37.9	35.3	350	333	442	322	1026.3	872.4	1007.0	853.3
Millat-11	44.8	42.1	43.7	40.6	444	422	436	413	1413.3	1201.3	1397.3	1177.0
Hashim-10	35.3	28.2	34.7	27.7	314	298	306	291	661.7	529.3	651.7	513.0

N = Normal condition, D = Drought condition, TGW = Thousand grain weight, PT = Productive tillers.
BY = Biological yield.

(9.9% and 9.6%)}, during first and second season, respectively (Table 2). Khakwani et al., 2012 reported significant loss in yield attributes when to evaluate the response of six wheat genotypes to different levels of drought stress and normal conditions regarding yield and yield components parameters. Bayoumi et al. (2008) and Lopes and Reynolds, (2010) also reported the similar finding as difference in results may be because of the dissimilarities in experimental area circumstances.

3.2. Impact of normal and drought conditions on biological yield and its components

For estimation of the most and less drought affected wheat genotypes during 2015–2016 and 2016–2017 seasons, the analysed data of biological yield of wheat depicted a significant impact of terminal drought on the biological yield of different wheat genotypes. In normal water conditions, plants exhibited higher biological yield, while the imposed drought stress significantly reduced the biological yield. Under both normal and stress conditions, Hashim-10, Punjab-11, Watan-92, Faisalabad-85 and Shafaq-06 were the genotypes which showed low yield while the genotypes MH-97, 9444, Pirsabak-04, Faisalabad-83 and Punjab-85 showed high biological yield. Genotypes Pothohar-73, Kohsar-95 and Parwaz-94 showed high yield under normal conditions but produced low grain yield in drought conditions, thus higher biological yield loss was observed. The biological yield losses were presumably directed to ripening of photosynthetic portions prematurely which hampered photosynthesis and resultantly less grain yield. Same findings found by Pierivatolum et al. (2010) who considered the impact of drought stress on biological yield of 4 wheat genotypes and depicted that resistant genotypes showed greater biological and grain yield.

Table 2
Average yield components of 50 wheat (*Triticum aestivum* L.) genotypes under normal and drought conditions during the 2015–2016 and 2016–2017 growing seasons.

Genotypes	HI				GY				YR		MYR
	2015/16		2016/17		2015/16		2016/17		2015/16	2016/17	
	N	D	N	D	N	D	N	D			
Pb-11	32.2	31.9	31.0	31.4	211.7	188.6	202.0	178.0	11.0	11.9	11.5
Gomal-08	33.7	33.4	32.7	32.8	275.7	245.7	265.7	235.0	10.9	11.5	11.2
Iqbal-00	32.8	28.2	31.5	28.1	278.0	216.7	267.3	208.0	22.5	22.2	22.3
Pak 81	32.7	32.3	31.6	31.5	292.3	260.0	280.7	250.3	11.1	10.8	11.0
Watan-92	32.3	30.0	31.4	29.1	223.0	186.0	214.7	176.0	16.6	18.0	17.3
Saher-06	30.1	29.9	29.5	29.9	355.0	318.0	345.7	308.3	10.7	10.8	10.7
9495	31.6	27.8	28.2	26.9	390.3	309.3	346.7	296.0	21.0	13.0	17.0
Pb-85	30.0	28.4	29.5	28.2	385.3	328.2	375.7	318.0	14.8	15.4	15.1
LU-26	37.8	36.0	36.9	35.1	306.6	262.6	297.0	252.0	14.4	15.2	14.8
Moomal-02	30.4	29.1	29.8	28.9	372.3	321.8	362.0	310.0	13.8	14.4	14.1
Kohistan-97	32.0	31.5	31.3	31.2	408.2	362.0	396.3	353.3	11.4	10.8	11.1
Fsd-83	32.1	32.0	31.2	31.3	425.5	385.4	415.3	375.3	9.9	9.6	9.8
Aas-11	32.3	30.5	31.7	30.4	314.1	267.1	305.0	258.0	15.0	15.4	15.2
Kohsar-95	31.3	24.1	30.7	23.6	354.6	246.8	345.7	236.0	30.7	31.7	31.2
Fsd-08	29.0	25.6	27.9	25.0	346.6	276.3	336.0	265.7	20.4	20.9	20.7
Uqab-00	32.1	31.5	31.8	31.4	402.5	335.1	394.7	325.0	16.7	17.7	17.2
GA-02	30.8	34.9	30.5	34.5	282.7	272.3	277.3	261.3	3.8	5.6	4.7
Glaxy-13	29.3	29.2	28.5	28.9	302.7	256.2	292.7	244.3	15.4	16.5	16.0
Chakwal-50	35.2	35.0	34.1	34.8	406.0	344.0	395.7	334.7	15.3	15.4	15.4
Bhakhar-02	30.8	29.4	30.3	29.3	391.7	317.9	382.0	309.3	18.9	19.0	18.9
Pbw-222	32.4	31.9	32.0	30.9	425.1	355.2	415.3	338.7	16.2	18.5	17.4
MH-97	36.3	36.2	35.3	35.5	468.9	398.1	458.0	387.0	15.2	15.5	15.3
Fareed-06	35.4	35.3	35.0	35.1	453.7	383.9	444.0	374.0	15.4	15.8	15.6
Shaheen-94	31.7	30.3	31.2	29.9	403.3	328.1	394.0	318.0	18.7	19.3	19.0
Bathoor-08	30.5	30.0	30.0	30.2	363.7	302.7	353.3	295.7	16.5	16.3	16.4
Pirsabak-04	34.8	34.7	34.1	34.6	465.2	395.6	454.0	386.0	15.1	15.0	15.1
Fsd-85	34.3	32.8	33.8	32.8	240.7	195.1	230.7	187.0	18.9	18.9	18.9
Shafaq-06	34.5	32.5	33.8	32.7	240.7	192.8	230.3	186.3	19.9	19.1	19.5
Kohinoor-83	34.3	28.1	33.9	28.2	471.2	328.1	461.7	319.3	30.4	30.8	30.6
Manthar-03	32.9	32.0	32.3	31.6	403.2	334.7	393.3	324.3	17.2	17.5	17.4
Lasani-06	32.9	31.9	32.3	31.9	401.8	332.8	391.3	323.7	17.5	17.3	17.4
9610	29.8	29.3	29.4	28.5	304.0	254.7	294.0	244.3	16.3	16.9	16.6
SH-02	31.7	28.1	31.2	27.6	403.3	304.2	393.3	294.0	24.6	25.2	24.9
Parsab-08	28.6	27.4	27.8	27.0	348.0	283.4	336.7	274.3	18.6	18.5	18.6
Anmol-91	32.2	31.9	31.5	31.8	387.7	328.2	376.7	319.3	15.4	15.2	15.3
Aas-02	28.6	28.0	27.8	27.2	296.0	231.3	284.7	222.0	21.9	22.0	21.9
Parwaz-94	31.2	26.9	30.9	26.5	371.2	255.9	361.0	245.0	31.3	32.1	31.7
9444	35.0	34.3	34.6	33.8	468.1	419.4	458.0	409.7	10.5	10.6	10.5
Inquilab-91	34.4	34.1	33.8	34.2	454.1	360.4	444.0	350.0	20.6	21.2	20.9
Potohar-73	31.3	30.9	31.1	30.5	402.7	318.1	395.3	309.3	21.0	21.8	21.4
Pict-62	32.7	32.8	32.4	33.0	414.7	332.9	406.7	326.0	19.7	19.8	19.8
Wafaq-01	31.1	30.5	31.0	29.8	317.0	249.0	309.0	237.3	21.4	23.2	22.3
AARI-11	31.3	28.9	30.7	28.8	400.7	296.5	390.0	287.3	26.0	26.3	26.2
NARC-08	29.7	27.0	29.4	26.9	354.3	257.6	344.0	248.0	27.4	27.9	27.6
Chenab-00	33.7	29.2	33.5	28.7	467.9	324.1	457.0	314.7	30.6	31.2	30.9
Abadghar-93	31.3	28.0	30.5	27.6	399.3	285.9	386.3	276.3	28.4	28.5	28.4
9725	33.8	32.5	33.7	32.4	471.2	384.3	461.7	376.7	18.3	18.4	18.3
SH-95	29.9	29.4	29.1	28.7	307.3	256.7	292.7	245.0	16.5	16.3	16.4
Millat-11	33.6	32.5	33.3	32.3	475.3	390.3	465.0	380.3	17.8	18.2	18.0
Hashim-10	34.0	30.5	33.0	30.3	224.7	161.2	215.0	155.3	28.2	27.7	28.0

N = Normal condition, D = Drought condition, HI = Harvest index, GY = Grain yield YR = Yield reduction MYR = Mean yield reduction.

TGW, as an imperative yield contributing attribute with a pivotal character in restrictive yield potential, also decreased significantly with drought. Genotypes Kohenoor-83, Kohsar-95 and Parwaz-94 showed TGW under normal conditions but produced low grain yield in stress condition. Warrington et al. (1977) explicated that drought stress at flowering and grain filling stage may direct to yield reduction by falling TGW, and if it along with high temperature accelerates whole plant senescence and decreases BY and Harvest index. Number of PT is also a vital yield additive aspect for achieving higher yield as greater number of PT validate higher final yield. Plants formed more productive tillers in normal condition, while drought stress drastically reduced this trait.

Harvest Index is the competence of a genotype for translocation of assimilates in economically imperative part of crop. Under normal conditions, minimum values of harvest index (28.6, 27.8) were observed by the Parsab-08 as well as Aas-02 in 2015–2016 and 2016–2017 and maximum values (37.8 and 36.9) were found in LU-26, while in stress conditions, minimum and maximum values were observed in Kohsar-95 (24.1 and 23.6) and MH-97 (36.20 and 35.5) respectively. Harvest index decreased under drought conditions since both biological and grain yields decreased at different rates. Decrease in the value of harvest index possibly because of impact on yield and higher enhance in biological yield comparatively in grain yield. Same results were found by Khakwani et al., 2012 who reported significant loss in yield attributes of harvest index, biological yield and TGW on the same pattern when to evaluate the response of six wheat genotypes to different levels of drought stress and normal conditions.

3.3. Drought tolerance indices

The highest values of tolerance index (TOL) belonged to genotypes Chenab-00, Kohinoor-08, Parwaz-94, Abadghar-93, Kohsar-95 and AARI-11 having the values of 286.1, 285.5, 231.4, 223.4, 217.5, 206.9 respectively and the highest values of stress susceptibility index (SSI) belonged to genotypes Parwaz-94, Kohsar-95, Chenab-00, Kohinoor-08 and having the values of 1.7, 1.7, 1.7 and 1.6 respectively (Table 3). Under normal conditions, these genotypes showed high yield but low yield in drought conditions and thus were recognized as sensitive ones. Although these genotypes produced high yields, but for cultivation over wide range of areas these are not appropriate on account of their high losses of grain yield. It implies that choice on the bases of high TOL and SSI values would outcome low yielding and sensitive genotypes in drought conditions.

The least values of tolerance index (TOL) belonged to genotypes GA-02 and Punjab-11 having value of 26.4 g m^{-2} and 47.1 g m^{-2}. Dorostkar et al. (2015), Khakwani et al. (2011), Aghaei-Sarbarze et al. (2009) and Rosielle and Hamblin, (1981) recommended that least values of TOL and SSI are related to least sensitivity to drought and choice exclusively on the bases of these indices directs high yielding genotypes under drought conditions. While TOL index illustrates the grain yield differences in normal (Yp) and drought (Ys) conditions.

3.4. Correlation analysis

There were positive significant correlations between Yp and all drought tolerance indices expect DI. For example, yield under non-stress conditions (Yp) showed a correlation of 0.981 with GMP, 0.985 with MP and 0.581 with TOL (Table 4). Ys was positively correlated with GMP (r = 0.983), MP (r = 0.979) but negatively correlated with SSI (r = −0.240). These correlations indicate that genotypes with higher MP and GMP are superior under stress conditions. These results are in agreement with those reported by Fernandez (1992) in bean and by Reynolds et al. (2007) and Dorostkar et al. (2015) in wheat. All these studies inspected the selection criteria effectiveness for evaluating plant drought tolerance and reported that TOL, MP and GMP are more suitable to screen tolerance as they showed high positive correlation with

Table 3
Influences under normal drought stress conditions on mean grain yields and drought indices for 50 wheat (*Triticum aestivum* L.) genotypes.

Genotypes	Yp	Ys	TOL	DI	MP	SSI	GMP
Pb-11	413.7	366.6	47.1	0.89	390.1	0.6	389.4
Gomal-08	541.3	480.7	60.7	0.89	511.0	0.6	510.1
Iqbal-00	545.3	424.7	120.7	0.78	485.0	1.2	481.2
Pak 81	573.0	510.3	62.7	0.89	541.7	0.6	540.8
Watan-92	437.7	362.0	75.7	0.83	399.8	0.9	398.0
Saher-06	700.7	626.3	74.3	0.89	663.5	0.6	662.5
9495	737.0	605.3	131.7	0.82	671.2	1.0	667.9
Pb-85	761.0	646.2	114.8	0.85	703.6	0.8	701.2
LU-26	603.6	514.6	89.0	0.85	559.1	0.8	557.3
Moomal-02	734.3	631.8	102.5	0.86	683.1	0.7	681.1
Kohistan-97	804.5	715.3	89.2	0.89	759.9	0.6	758.6
Fsd-83	840.9	760.7	80.1	0.90	800.8	0.5	799.8
Aas-11	619.1	525.1	94.0	0.85	572.1	0.8	570.2
Kohsar-95	700.3	482.8	217.5	0.69	591.5	1.7	581.4
Fsd-08	682.6	542.0	140.6	0.79	612.3	1.1	608.2
Uqab-00	797.1	660.1	137.0	0.83	728.6	0.9	725.4
GA-02	560.0	533.6	26.4	0.95	546.8	0.3	546.7
Glaxy-13	595.3	500.6	94.8	0.84	548.0	0.9	545.9
Chakwal-50	801.6	678.7	123.0	0.85	740.2	0.8	737.6
Bhakhar-02	773.7	627.2	146.5	0.81	700.4	1.0	696.6
Pbw-222	840.4	693.9	146.5	0.83	767.2	0.9	763.7
MH-97	926.9	785.1	141.8	0.85	856.0	0.8	853.1
Fareed-06	897.7	757.9	139.8	0.84	827.8	0.8	824.8
Shaheen-94	797.3	646.1	151.3	0.81	721.7	1.0	717.7
Bathoor-08	717.0	598.4	118.6	0.83	657.7	0.9	655.0
Pirsabak-04	919.2	781.6	137.6	0.85	850.4	0.8	847.6
Fsd-85	471.3	382.1	89.2	0.81	426.7	1.0	424.4
Shafaq-06	471.0	379.2	91.8	0.81	425.1	1.0	422.6
Kohinoor-83	932.9	647.4	285.5	0.69	790.2	1.6	777.1
Manthar-03	796.5	659.1	137.4	0.83	727.8	0.9	724.5
Lasani-06	793.1	656.5	136.6	0.83	724.8	0.9	721.6
9610	598.0	499.0	99.0	0.83	548.5	0.9	546.3
SH-02	796.7	598.2	198.5	0.75	697.4	1.3	690.3
Parsab-08	684.7	557.8	126.9	0.81	621.2	1.0	618.0
Anmol-91	764.4	647.5	116.9	0.85	706.0	0.8	703.5
Aas-02	580.7	453.3	127.4	0.78	517.0	1.2	513.0
Parwaz-94	732.2	500.9	231.4	0.68	616.6	1.7	605.6
9444	926.1	829.1	97.0	0.90	877.6	0.6	876.2
Inquilab-91	898.1	710.4	187.6	0.79	804.3	1.1	798.8
Potohar-73	798.0	627.4	170.6	0.79	712.7	1.1	707.6
Pict-62	821.4	658.9	162.5	0.80	740.2	1.1	735.7
Wafaq-01	626.0	486.3	139.7	0.78	556.2	1.2	551.8
AARI-11	790.7	583.8	206.9	0.74	687.2	1.4	679.4
NARC-08	698.3	505.6	192.8	0.72	602.0	1.5	594.2
Chenab-00	924.9	638.8	286.1	0.69	781.9	1.7	768.7
Abadghar-93	785.7	562.2	223.4	0.72	674.0	1.5	664.6
9725	932.9	761.0	171.9	0.82	846.9	1.0	842.6
SH-95	600.0	501.7	98.3	0.84	550.9	0.9	548.7
Millat-11	940.3	770.7	169.7	0.82	855.5	1.0	851.3
Hashim-10	439.7	316.5	123.1	0.72	378.1	1.5	373.1

Yp = Yield under normal condition, Ys = Yield under drought condition, TOL = Tolerance index, DI = Drought index, MP = Mean productivity, GMP = Geometric mean productivity, SSI = Stress susceptibility index

Table 4
Correlation coefficients between yield under normal (Yp) and drought (Ys) conditions and drought tolerance indices.

	DI	GMP	MP	SSI	TOL	Yp
GMP	0.065					
MP	0.044	0.999**				
SSI	−0.998**	−0.066	−0.045			
TOL	−0.861**	0.415**	0.435**	0.861**		
Yp	−0.121	0.981**	0.985**	0.120	0.581**	
Ys	0.239	0.983**	0.979**	−0.240	0.246	0.931**

** = Highly significant at $p \leq 0.01$. Yp = yield under normal condition, Ys = Yield under drought condition, SSI = Stress susceptibility index, MP = Mean productivity, TOL = Tolerance index, DI = Drought index, GMP = Geometric mean productivity.

grain yield under both drought and normal conditions. Positive significant correlation between GMP and MP and TOL in both drought and normal conditions shows that their effects are stronger than those of SSI and DI (Sio-Se Mardeh et al. 2006; Geravandi et al. 2010). There was a high correlation between MP and GMP (r = 0.999). Since GMP is calculated based on MP. So, high values of MP distinguish high-yielding drought tolerant wheat genotypes. Same results were attained by Fernandez (1992), Farshadfar and Sutka (2003) and Khakwani et al. (2011). All these studies exhibited positive correlation between grain yield (both drought and normal conditions) and MP and GMP which recommend that these indices direct to high yielding tolerant genotypes under drought environments.

4. Conclusion

Employing drought tolerant and high yielding genotypes is the proficient way to diminish the drought effects. Assessment of genotypes using physiological and morphological characters under normal and drought conditions is suitable method for achieving this goal. In the present study, two irrigation regimes (normal and drought stress conditions) were used for the genotypes evaluation in combination with different drought indices like mean productivity (MP), stress susceptibility index (SSI), drought index (DI), geometric mean productivity (GMP) and tolerance index (TOL). Statistical analysis depicted that genotypes GA-02, Faisalabad-83, 9444, Sehar-06, Pirsabak-04 and Kohistan-97 were more tolerant and recognized as suitable for both normal and drought conditions on account of their low grain yield loss. Thus, they can be exploited to transmit tolerance genes to commercial genotypes in crossing nurseries. Genotypes of Chenab-00, Kohsar-95, Parwaz-94 and Kohenoor-83 confirmed more sensitive due to high grain yield loss under drought stress and, thus, can be exercised for further drought controlling programs.

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