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

Hafiz Arslan Anwaara, Rashida Perveena, Muhammad Zeeshan Manshab, Muhammad Abida, Zahid Mahmood Sarwarc, Hafiz Muhammad Aatifb, Ummad ud din Umara, Muhammad Sajida, Hafiz Muhammad Usman Aslamc, Muhammad Mohsin Alam, Muhammad Rizwan, Rao Muhammad Ikram, Suliman Mohammed Suliman Alghanem, Abdul Rashid, Khalid Ali Khani

Department of Plant Pathology, Bahauddin Zakariya University (BZU), Multan, Pakistan

**Corresponding author.**

E-mail address: m181207w@st.u-gakugei.ac.jp (A. Rashid).

Peer review under responsibility of King Saud University.

---

**Article info**

Article history:
Received 21 September 2019
Revised 28 November 2019
Accepted 8 December 2019
Available online 17 December 2019

**Keywords:**
Drought
Grain yield
Tolerance index
Tolerance

**Abstract**

Drought stress constrains 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.

© 2019 The Author(s). Published by Elsevier B.V. on behalf of King Saud University. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

---

**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 fulfill the needs of burgeoning population which can only be accomplished when the production of cereal
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 inheritability. 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 Agriculture, Faisalabad (UAF) and Wheat Research Institute of Ayoub Agriculture Research Institute (AARI) for evaluating their performance 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.

\[ SI = 1 - \frac{Y_s}{Y_p} \]  
\[ SSI = \left( 1 - \frac{Y_s}{Y_p} \right) / SI \]  
\[ TOL = Y_p - Y_s \]  
\[ MP = (Y_p + Y_s) / 2 \]  
\[ GMP = \sqrt{Y_p \times Y_s} \]  
\[ DI = \frac{Y_s}{Y_p} \]

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 Kohnoor-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, Pir sabak-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 Kohnoor-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 Kohnoor-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
The impact of terminal drought on the biological yield of different genotypes during 2015–2016 and 2016–2017 seasons, the difference in results may be because of the dissimilarities in experimental area circumstances.

### 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 |
|-----------|-----|----|----|
| N | D | N | D | N | D | N | D |
| Sh-95 | 38.5 | 33.6 | 38.3 | 33.4 | 391 | 367 | 382 | 357 |
| Abadghar-93 | 41.3 | 39.5 | 32.8 | 31.3 | 401 | 392 | 395 | 383 |
| 9444 | 44.7 | 43.9 | 41.1 | 40.7 | 429 | 411 | 416 | 408 |
| Pirsabak-04 | 42.3 | 39.1 | 38.0 | 37.7 | 403 | 391 | 392 | 387 |
| Pict-62 | 42.2 | 38.8 | 37.9 | 37.5 | 414 | 405 | 409 | 404 |
| Anmol-91 | 39.5 | 37.3 | 37.1 | 36.7 | 386 | 374 | 379 | 375 |
| Fsd-83 | 40.5 | 38.3 | 37.1 | 36.7 | 399 | 387 | 392 | 388 |
| Pb-11 | 38.3 | 36.1 | 35.8 | 35.4 | 393 | 382 | 388 | 384 |
| Fsd-08 | 40.7 | 38.5 | 37.4 | 37.1 | 404 | 393 | 398 | 393 |
| Kohsar-95 | 41.1 | 38.9 | 37.7 | 37.3 | 406 | 395 | 402 | 398 |
| Kohistan-97 | 42.3 | 39.1 | 38.0 | 37.6 | 417 | 405 | 412 | 408 |
| GP-62 | 39.5 | 37.3 | 36.8 | 36.4 | 396 | 384 | 389 | 386 |
| 9495 | 41.8 | 39.6 | 38.4 | 38.0 | 424 | 413 | 418 | 414 |
| Pbh-222 | 43.2 | 40.0 | 38.9 | 38.5 | 427 | 415 | 421 | 417 |
| Aas-11 | 38.9 | 36.8 | 36.5 | 36.1 | 402 | 391 | 396 | 392 |
| Fsd-93 | 41.3 | 39.1 | 38.0 | 37.6 | 408 | 397 | 403 | 399 |
| Aas-02 | 38.9 | 36.8 | 36.5 | 36.1 | 403 | 392 | 398 | 394 |
| 9444 | 44.7 | 43.5 | 42.3 | 41.9 | 436 | 424 | 432 | 429 |
| 9495 | 41.8 | 39.6 | 38.4 | 38.0 | 424 | 413 | 418 | 414 |
| 9444 | 44.7 | 43.5 | 42.3 | 41.9 | 436 | 424 | 432 | 429 |
| 9444 | 44.7 | 43.5 | 42.3 | 41.9 | 436 | 424 | 432 | 429 |

**N** = Normal condition, **D** = Drought condition, **TGW** = Thousand grain weight, **PT** = Productive tillers.

### 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, Water-92, Faisalabad-85 and Shafaaq-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. Some findings found by Perivatlojum 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.
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) explained 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, 285.3, 231.4, 223.4, 290.8 and 246.7 respectively, which were 2.20, 2.16, 2.17, 2.22, 2.19 and 2.23 times greater than that of the lowest (TOL) genotypes in stress condition. Therefore, these genotypes can be considered as high drought tolerance indices, which can be used in breeding programs to improve the yield of wheat under drought stress.
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$^{-2}$.

Table 3

| Genotypes   | Yp   | Ys   | TOL   | DI   | MP   | GMP |
|-------------|------|------|-------|------|------|-----|
| Pb-11       | 413.7| 366.6| 47.1  | 0.89 | 390.1| 0.6 |
| Gomal-08    | 451.3| 480.7| 60.7  | 0.78 | 485.0| 1.2 |
| Iqbal-00    | 545.3| 424.7| 120.7 | 0.89 | 541.7| 0.6 |
| Pak 81      | 573.0| 510.3| 75.7  | 0.83 | 399.8| 0.5 |
| Watan-92    | 437.7| 362.0| 74.3  | 0.89 | 663.5| 0.6 |
| Saher-06    | 700.7| 626.7| 131.7 | 0.82 | 671.2| 1.0 |
| 9495        | 737.0| 605.3| 6.7   | 0.89 | 732.6| 1.2 |
| Pb-85       | 761.0| 480.7| 114.8 | 0.85 | 706.3| 0.8 |
| LU-26       | 603.6| 514.6| 89.0  | 0.85 | 559.1| 0.8 |
| Moorni-02   | 734.3| 631.8| 102.5 | 0.86 | 683.1| 0.7 |
| Kohistan-97 | 804.5| 715.3| 137.0 | 0.83 | 726.6| 0.9 |
| Fsd-08      | 840.9| 760.7| 80.1  | 0.90 | 708.0| 0.5 |
| Aas-11      | 619.1| 525.1| 94.0  | 0.85 | 572.1| 0.8 |
| Kohsen-95   | 700.3| 482.8| 217.5 | 0.69 | 591.5| 1.7 |
| Fsd-85      | 682.6| 542.0| 140.6 | 0.79 | 612.3| 1.1 |
| Usqab-00    | 791.7| 660.1| 137.0 | 0.83 | 726.6| 0.9 |
| GA-02       | 560.0| 533.6| 26.4  | 0.95 | 546.8| 0.3 |
| Glaxy-13    | 595.3| 500.6| 94.8  | 0.84 | 548.0| 0.9 |
| Chakwal-50  | 801.6| 678.7| 123.0 | 0.85 | 740.2| 0.8 |
| Bhakkar-02  | 773.7| 627.2| 146.5 | 0.81 | 706.4| 1.0 |
| Pb-222      | 840.4| 693.9| 146.5 | 0.83 | 767.2| 0.9 |
| MH-97       | 926.9| 785.1| 141.8 | 0.85 | 856.0| 0.8 |
| Fareed-06   | 897.7| 757.9| 139.8 | 0.84 | 827.8| 0.6 |
| Shaheen-94  | 797.3| 646.1| 151.3 | 0.81 | 721.7| 1.0 |
| Bathnar-08  | 717.0| 598.2| 118.6 | 0.83 | 657.7| 0.9 |
| Pirsabak-04 | 919.2| 781.6| 137.6 | 0.85 | 854.0| 0.8 |
| Fsd-85      | 471.3| 382.1| 89.2  | 0.82 | 426.7| 1.0 |
| Shafaq-06   | 471.0| 379.2| 91.8  | 0.81 | 425.1| 1.0 |
| Kohsen-83   | 932.9| 647.4| 253.5 | 0.69 | 790.2| 1.6 |
| Manthan-03  | 796.5| 659.1| 137.4 | 0.83 | 727.8| 0.9 |
| Lasani-06   | 793.1| 656.5| 136.6 | 0.83 | 724.8| 0.9 |
| 9610        | 598.0| 499.0| 99.0  | 0.83 | 548.5| 0.9 |
| SH-02       | 796.7| 598.2| 198.5 | 0.75 | 697.4| 1.3 |
| Parshab-08  | 684.7| 557.8| 126.9 | 0.81 | 621.2| 1.0 |
| Anmol-91    | 764.4| 647.5| 116.9 | 0.84 | 706.5| 0.8 |
| Aas-02      | 580.7| 453.3| 127.4 | 0.78 | 517.0| 1.2 |
| Parwaz-94   | 732.2| 500.9| 231.4 | 0.68 | 616.6| 1.7 |
| 9444        | 926.1| 829.1| 97.0  | 0.90 | 877.6| 0.6 |
| Inqubal-91  | 858.1| 710.4| 187.6 | 0.79 | 804.3| 1.1 |
| Potbar-73   | 798.0| 627.4| 170.6 | 0.79 | 712.7| 1.1 |
| Pct-62      | 821.4| 658.9| 162.5 | 0.80 | 740.2| 1.1 |
| Wafaq-01    | 626.0| 486.3| 139.7 | 0.78 | 556.2| 1.2 |
| AARI-11     | 790.7| 583.8| 206.9 | 0.74 | 687.2| 1.4 |
| NARC-08     | 698.3| 505.6| 192.8 | 0.72 | 602.0| 1.5 |
| Chenab-00   | 924.9| 638.8| 286.1 | 0.69 | 781.9| 1.7 |
| Abdaghar-93 | 748.7| 562.2| 223.4 | 0.72 | 674.0| 1.5 |
| 9725        | 932.9| 761.0| 171.9 | 0.82 | 846.9| 1.0 |
| SH-95       | 600.0| 501.7| 98.3  | 0.84 | 550.9| 0.9 |
| Millat-11   | 940.3| 776.7| 169.7 | 0.82 | 855.5| 1.0 |
| Hashim-10   | 439.7| 316.5| 123.1 | 0.72 | 378.1| 1.5 |

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

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...
grain yield under both drought and normal conditions. Positive significant correlation between CMP 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 and Farshadfar 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, Pirisabak-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.

Acknowledgements

Authors are thankful to Bahauddin Zakariya University (RZU), Multan and University of Agriculture, Faisalabad for providing laboratory facilities to conduct this research. Khalid Ali Khan extends his appreciation to the Deanship of Scientific Research at King Khalid University for support through research group program (R.G.P.1)-108/40.

References

Aghaei-Sarbarze, R.M., Mohammadi, R., Haghparast, R., Rajabi, R. 2009. Determination of drought tolerant genotypes in bread wheat. Electronic J. Crop Prod. 2, 1–23
Ahmad, F., Iqbal, N., Zaka, S.M., Qureshi, M.K., Saed, Q., Khan, K.A., Chramb, H.A., Ansari, M.J., Jaleel, W., Aasim, M., Awar, M.B., 2019. Comparative insecticidal activity of different plant materials from six common plant species against Tribolium castaneum (Herbst) (Coleoptera: Tenebrionidae). Saudi J. Biol. Sci. 26 (7), 1804–1808. https://doi.org/10.1016/j.sjbs.2018.02.016
Ahmed, H.C.M.D., Mustafa, S., 2017. Designate the inheritance pattern of yield related indices in spring wheat. J. Agric. Basic Sci. 2, 50–57.
Ansari, M.J., Kumar, R., Singh, K., Dhaliwal, H.S., 2014. Characterization and molecular mapping of a soft glume mutant in diploid wheat (Triticum monococcum L.). Cereal Res. Commun. 42 (2), 209–217.
Bayoumi, T.Y., Eid, M.H., Metwali, E.M., 2008. Application of physiological and biochemical indices as a screening technique for drought tolerance in wheat genotypes. Afr. J. Biotechnol. 7, 14.
Dorostkar, S., Dadkhodaei, A., Heidari, B., 2015. Evaluation of grain yield indices in hexaploid wheat genotypes in response to drought stress. Arch. Agron. Soil Sci. 61, 397–413.
Farshadfar, E., Sutka, J., 2003. Multivariate analysis of drought tolerance in wheat substitution lines. Cereal Res. Commun. 31 (1–2), 33–40.
Farshadfar, E.C., 1999. 1992. Effective selection criteria for assessing plant stress tolerance. In: Kuo, C.G., (Ed.), Proceedings of the International Symposium on Adaptation of Vegetables and other Food Crops in Temperature and Water Stress. AVRDC Publication, Tainan, Taiwan. Shanhua, pp. 257–270. Chapter 25, 1992 Aug 13–16.
Field, C.B., 2012. Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation: Special Report of the Intergovernmental Panel on Climate Change. IPCC. Cambridge University Press, UK.
Fischer, R.A., Maurer, R., 1978. Drought resistance in spring wheat cultivars. I. Grain yield responses. Australian J. Agric. Res. 29, 897–912. https://doi.org/10.1071/AR9780907.
Geravandi, M., Farshadfar, M., Kahrizi, D., 2010. Evaluation of drought tolerance in bread wheat advanced genotypes in field and laboratory conditions. Seed Plant Improvement J. 26, 233–252.
Khakwani, A.A., Bennett, M.D., Munir, M. 2011. Drought tolerance screening of wheat varieties by inducing water stress conditions. SongklaKanakinar J. Sci. Technol. 33, 135–142.
Khakwani, A.A., Bennett, M.D., Munir, M., Abid, M., 2012. Growth and yield response of wheat varieties to water stress at booting and anthesis stages of development. Pakistan Journal of Botany 44 (3), 879–886.
Lopes, M.S., Reynolds, M.P., 2010. Partitioning of assimilates to deeper roots is associated with cooler canopies and increased yield under drought in wheat. Funct. Plant Biol. 37, 147–156.
Mitra, J., 2001. Genetics and genetic improvement of drought resistance in crop plants. Crop Sci. 80, 758–762.
Perivotalos, J., Kasinov, N., Marcalian, H., 2010. Effect of soil water stress on yield and proline content of four wheat lines. Afr. J. Biotechnol. 9, 36–40.
Reynolds, M.P., Saint, P.C., Saad, A.S.I., Vargas, M., Condon, A.G., 2007. Evaluating potential genetic gains in wheat associated with stress-adaptive trait expression in elite genetic resources under drought and heat stress. Crop Sci. 47, 172–189. https://doi.org/10.2135/cropsci2007.10.0221PBS.
Rosie, A., Hamblin, J., 1981. Theoretical aspects of selection for yield in stress and non-stress environment. Crop Sci. 21, 943–946. https://doi.org/10.2135/cropsci1981.0011393x0021000900133x.
Sio-Se Mardeh, A., Ahmad, A., Poustini, K., Mohammadi, V., 2006. Evaluation of drought resistance indices under various environmental conditions. Field Crops Res. 98, 222–229. https://doi.org/10.1016/j.fcr.2006.02.001.
Solomon, S., 2007. Climate change 2007—the Physical Science Basis: Working Group I Contribution to the Fourth Assessment Report of the IPCC. Cambridge University Press.
USDA 2016–17. World Agriculture Production, United States Department of Agriculture, USA.
Warrington, I.J., Dunstone, R., Green, L.M., 1977. Temperature effects at three temperature levels on wheat. Cereal Res. Commun. 61, 397–413.
Yadav, O.P., Bhagtaagar, S.K., 2001. Evaluation of indices for identification of pearl millet cultivars adapted to stress and non-stress conditions. Field Crops Res. 70, 201–208. https://doi.org/10.1016/S0378-4290(01)00138-1.

Table 4

| Yp | Yp | Yp | Yp |
|---|---|---|---|
| **** | **** | **** | **** |
| Yp | Yp | Yp | Yp |
| **** | **** | **** | **** |
| Yp | Yp | Yp | Yp |
| **** | **** | **** | **** |
| Yp | Yp | Yp | Yp |
| **** | **** | **** | **** |
| Yp | Yp | Yp | Yp |
| **** | **** | **** | **** |
| Yp | Yp | Yp | Yp |
| **** | **** | **** | **** |
| Yp | Yp | Yp | Yp |
| **** | **** | **** | **** |
| Yp | Yp | Yp | Yp |
| **** | **** | **** | **** |
| Yp | Yp | Yp | Yp |
| **** | **** | **** | **** |
| Yp | Yp | Yp | Yp |
| **** | **** | **** | **** |
| Yp | Yp | Yp | Yp |
| **** | **** | **** | **** |
| Yp | Yp | Yp | Yp |
| **** | **** | **** | **** |

** = Highly significant at p ≤ 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.