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Original Research Article

SCREENING OF WHEAT GENOTYPES FOR WATER DEFICIT CONDITIONS UNDER THE SCENARIO OF CLIMATE CHANGE

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Abstract *The top-ranked crop in cereals, wheat feeds people around the globe more than any other food crop, with a diversity of uses in the food industry. The global production of wheat is 250 million tons which is still not enough to address the needs of the ever-increasing human population. Wheat plays a vital role in the human diet because it is the source of protein, carbohydrates, and calories. Due to its wider adaptation wheat is sown as a rain-fed and irrigated crop. Drought upsets the crop during all growth and developmental stages and all these stages of the crop are not equally affected by the drought. At initial growth stages, water stress reduces plant emergence and germination and causes a reduction in plant growth by reducing its height, number of productive tillers, and total leaf surface area. When drought occurs at anthesis it reduces the percentage of fertile spikelets. This research aimed to check the response of wheat genotypes under drought stress for different morphological attributes at the maturity stage. Significant results were obtained under drought and normal conditions. The data were further analyzed under PCA for the selection of best genotypes under normal and stress conditions. Zincol performed well under both conditions. Results obtained from this research will be useful in selecting the best genotypes for rainfed and water-stress environments in future breeding programs.*

Keywords: *wheat; drought; yield; PCA; genotypes*

Introduction

Wheat is the staple food in Pakistan and it adds 8.9% of the Agriculture sector with 1.6% of the GDP. The production was 25076 thousand tons in 2017-18 and increased by 0.5% (20195 thousand tons) in 2018-19 but fell short of 4.9% of the target. The total area for wheat was 8700 thousand hectares in 2017-18 which decreased by 0.6% in 2018-19. The area was decreased due to the unavailability of water resources, shifting to other competitive crops and weather conditions (Daoura et al., 2013). Drought stress severely affects all the growth stages of wheat but the grain filling period is most sensitive to water shortage. Wheat is very sensitive to drought just before flowering and pollination (Verma et al., 2019).

Certain environmental factors interact with plant growth throughout the crop period such as temperature, radiation, nutrients, and humidity. The increase or decrease in their value leads to imbalance and causes the reduction in plant growth by limiting the concentration of growth factors and the damages are often reversible (Edae, 2013). The crop growth and development stages are continuously affected by various stresses and cause yield losses in the world. Among these stresses' drought poses a sever risk to successful crop production and is considered as a crop performance restraining factor (Kocheva et al., 2014).

Wheat is cultivated in both irrigated and rainfed conditions and in developing countries, 50% of

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wheat growing area is under rainfed environment (El-Hendawy et al., 2017). Drought stress occurs at different regions of the world and permanently affects the area (Zhao et al., 2020). Severe conditions of stress caused significant losses to total crop production and overall cropping area is decreasing (Ali et al., 2016; Ali et al., 2014b; Zhao et al., 2020). Among all abiotic and biotic stresses drought plays an important role in decreasing crop productivity (Dewey and Lu, 1959). It reduces the enzyme activity which is involved in carbon-metabolizing and limits the photosynthetic activity of the crop (Abbas et al., 2024a; Ali et al., 2014a; Zhang et al., 2019). It also decreased the grain weight when applied at the pre-anthesis stage by unbalancing the source-sink associations (Selote and Khanna-Chopra, 2006). To overcome this tolerant variety should be developed (Abbas et al., 2024b; Fatima et al., 2023; Haider et al., 2023; Reynolds et al., 2007). Drought is a serious threat and a main factor in decreasing crop growth, development, and yield. At initial growth stages, water stress reduces plant emergence and germination and causes a reduction in plant growth by reducing its height, number of productive tillers, and total leaf surface area. When drought occurs at anthesis it reduces the percentage of fertile spikelets (Ali et al., 2013; Ali et al., 2016; Islam et al., 2019). Drought stress also causes a reduction in grain weight and grain yield and reduces the grain filling duration of the crop. It also decreases the grain filling rate and leads to the total crop yield reduction (Sharma et al., 2005). The reduction in crop yield depends upon the intensity of drought stress which affects the all growth stages of the plant (Blum and Sullivan, 1997).

Crop yield is the complex combination of many physiological events and most of these events are negatively associated with drought stress. Pre-anthesis water stress decreased the grain-filling period of the crop (Singh et al., 2010). The enzymatic activity of the grain-filling period is reduced by the stress (Rizwan et al., 2017). Stress exposure at the anthesis and flowering stage caused the complete sterility observed in many cereal crops (Saifullah et al., 2014). It also decreased the photosynthetic activity by limiting the plant turgor pressure and water use efficiency (Sayar et al., 2010). Drought stress at the booting stage drastically reduced the grain size and weight (Zhang et al., 2013). A 50% yield reduction is observed when stress is applied at the flowering stage (Erenstein et al., 2021).

The statistical analysis of variance and mean values helps in evaluating the best-performing genotypes under all levels of treatment and provides a way for the selection of tolerant genotypes. correlation analysis provides the best combination of traits contributing to grain production (Tao et al., 2021). The correlation and biplot analysis for traits showed the strength of association and linear relationship between variables respectively. Grain yield showed a significant correlation with spike numbers (Tao et al., 2021). Improvement of crop varieties tolerant to drought is the fundamental objective of most plant breeding and research programs. Therefore, a current study was conducted to screen out the drought-tolerant varieties of bread wheat.

Objective

Screening out drought-tolerant genotypes that can be sown in the future to boost agricultural productivity.

Material and methods

The objective of the experiment was to investigate the potential impact of drought on the production and yield characteristics of ten distinct bread wheat varieties. The 2019-20 Rabi season saw the cultivation of these wheat cultivars in an experiment at the University of Agriculture Faisalabad, Pakistan. The genotypes used in this experiment are listed below.

(1). Inqlab-91 (2). Lasani-08 (3). Zincol (4). Eucora-70 5. T-9 (6). C-250 (7). C-273 (8). Pak-81 (9). Johar-16 (10). Galaxy-13. The random number approach was used to allocate treatments at random during the experiment's execution in a randomized complete block design. Seeds of these types were distributed in the field using a dibbler to maintain distance (P×P and R×R). The experiment involved two plots. One plot was kept in a drought-stricken condition (i.e., no water), whereas the other got regular watering. For data analysis, five plants from each genotype wereselected. Data was taken at maturity on different parameters i.e., Spike length, Peduncle length, 1000-grain weight, Number of spikelets per spike, Number of Productive tillers per plant, Yield per spike, Number of Grains per spike, Yield plant^{-1}, Plant height

PCA-Biplot Analysis

Biplot analysis of the traits was done to determine the better-adapted genotypes which can be further used in future research programs. Principle component analysis (PCA) showed the linear relationship between traits. PCA-Biplot analysis explored the mega environment trials data (Aslam et al., 2017).

Results and discussion

Genotypes exhibited significant results under drought and normal conditions. The data were further analyzed under PCA for the selection of best genotypes under normal and stress conditions. Principle component analysis is used to determine the linear relationship of variables having maximum variance. PCA-Biplot analysis showed the independent behavior of variables from each other. Principle component analysis is done for two

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irrigation levels, drought and normal for 10 wheat genotypes. 9 traits were subjected for analysis. Principle component analysis revealed that grain yield is related to 1000-grain weight, fertile tillers per plant, plant height, and plant vigor. The results from the PCA-biplot showed the association of wheat yield with days to flowering, chlorophyll content, and temperature. The genotypes performed well for these traits can be further used in breeding programs.

Plant Height

Data of 10 wheat genotypes was collected from the field experiment for plant height and the mean values were computed. PCA-Biplot analysis was plotted to check the linear relationship of variables having maximum variance and fitness of genotypes in normal and drought conditions. Genotype C-250 showed maximum value for plant height under both conditions of irrigation, normal, and drought. Inqlab-91 performed better under drought stress followed by Eucora-70. Genotype C-273 performed best under normal irrigation followed by Pak-81 and Johar-16. T-9 was the most sensitive genotype under drought as shown in Figure 1. Similar results were found by (Selote and Khanna-Chopra, 2006).

Number of Productive tillers per plant

Data from 10 wheat genotypes was collected from the field experiment for several productive tillers per plant and the mean values were computed. PCA-Biplot analysis was plotted to check the linear relationship of variables having maximum variance and fitness of genotypes in normal and drought conditions. Genotypes C-250 and Eucora-70 performed well for the number of productive tillers per plant under drought conditions of irrigation. Genotypes C-273 performed best under normal irrigation followed by Lasani-08. Genotype Inqlab-91 performed well under both levels of irrigation, normal and drought. T-9 was the most sensitive genotype for tillers per plant under drought stress as shown in Figure 2. Similar results were found by (Reynolds et al., 2007).

Spike Length

Data from 10 wheat genotypes was collected from the field experiment for spike length and the mean values were computed. PCA-Biplot analysis was plotted to check the linear relationship of variables having maximum variance and fitness of genotypes in normal and drought conditions. Under normal conditions of irrigation, genotype C-250 performed best for spike length. Genotype T-9 was most sensitive under drought stress. C-273 and Zincol performed better under both levels of irrigation. Inqlab-91 performed better under drought stress for spike length as shown in figure 3. Similar results were found by (Islam et al., 2019).

Peduncle Length

Data from 10 wheat genotypes was collected from the field experiment for peduncle length and the mean values were computed. PCA-Biplot analysis was plotted to check the linear relationship of variables having maximum variance and fitness of genotypes in normal and drought conditions. Genotypes Galaxy-13 and Johar-16 performed best under both levels of irrigation for peduncle length. Pak-81 was the most sensitive genotype under drought. C-273 and Zincol were best-performing genotypes under normal conditions of irrigation. Eucora-70 and Inqlab-91 performed best under drought conditions for peduncle length as shown in Figure 4. Similar results were found by (Sharma et al., 2005).

Spikelets per Spike

Data of 10 wheat genotypes was collected from the field experiment for spikelets per spike and the mean values were computed. PCA-Biplot analysis was plotted to check the linear relationship of variables having maximum variance and fitness of genotypes in normal and drought conditions. Under both conditions of irrigation genotypes C-273 and Lasani-08 performed best for the number of spikelets per spike. Genotype C-250 performed well under normal conditions. Eucora-70 and Johar-16 performed best under drought stress for spikelets per spike. T-9 was the most sensitive genotype under drought stress as shown in Figure 5. Similar results were found by (Blum and Sullivan, 1997).

Number of Grains per Spike

Data from 10 wheat genotypes was collected from the field experiment for the number of grains per spike and the mean values were computed. PCA-Biplot analysis was plotted to check the linear relationship of variables having maximum variance and fitness of genotypes in normal and drought conditions. Genotypes Eucora-70 and Galaxy-13 were best under both levels of irrigation for the number of grains per spike. Lasani-08 was best best-performing genotype under drought stress. Genotype Pak-81 was most sensitive to drought stress. Under normal conditions of irrigation, Zincol performed well followed by Inqlab-91 as shown in Figure 6. Similar results were found by (Ishtiaq et al., 2019; Rasheed et al., 2024; REHMAN et al., 2020; Singh et al., 2010).

Yield per Spike

Data of 10 wheat genotypes was collected from the field experiment for yield per spike and the mean values were computed. PCA-Biplot analysis was plotted to check the linear relationship of variables having maximum variance and fitness of genotypes in normal and drought conditions. Genotypes Galaxy-13 and Pak-81 performed best under normal irrigation for yield per spike followed by Pak-81. Eucora-70 was the most sensitive genotype under

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drought. Zincol, Inqlab-91, and Johar-16 performed well under drought stress. Under normal irrigation genotype, Lasani-08 performed best for yield per spike as shown in Figure 7. Similar results were found by (Sayar et al., 2010).

Grain Yield per Plant

Data of 10 wheat genotypes was collected from the field experiment for grain yield per plant and the mean values were computed. PCA-Biplot analysis was plotted to check the linear relationship of variables having maximum variance and fitness of genotypes in normal and drought conditions. Under normal irrigation genotype Galaxy-13 performed better for grain yield per plant followed by Pak-81. Genotype Inqlab-91 performed well under drought stress followed by Johar-16. Zincol performed well under both conditions of irrigation. Lasani-08 was sensitive under drought stress for grain yield per plant as shown in figure 8. Similar results were found by (Zhang et al., 2013).

1000-Grain Weight

Data of 10 wheat genotypes was collected from the field experiment for 1000-grain weight and the mean values were computed. PCA-Biplot analysis was plotted to check the linear relationship of variables having maximum variance and fitness of genotypes in normal and drought conditions. Genotype Inqlab-91 and Galaxy-13 performed better for 1000-grain weight under normal irrigation. Zincol and Lasani-08 performed well under drought stress followed by genotype T-9. Johar-16 was the most sensitive genotype under drought stress. Pak-81 and Inqlab-91 performed best under both conditions as shown in figure 9. Similar results were found by (Tao et al., 2021).

Plant Height

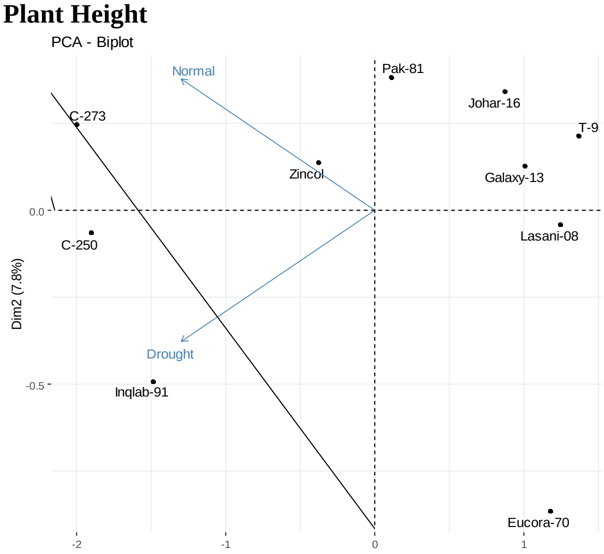

Figure 1 PCA-Biplot analysis of 10 genotypes of wheat under two levels of irrigation for plant height viz. normal and drought

Tillers per Plant

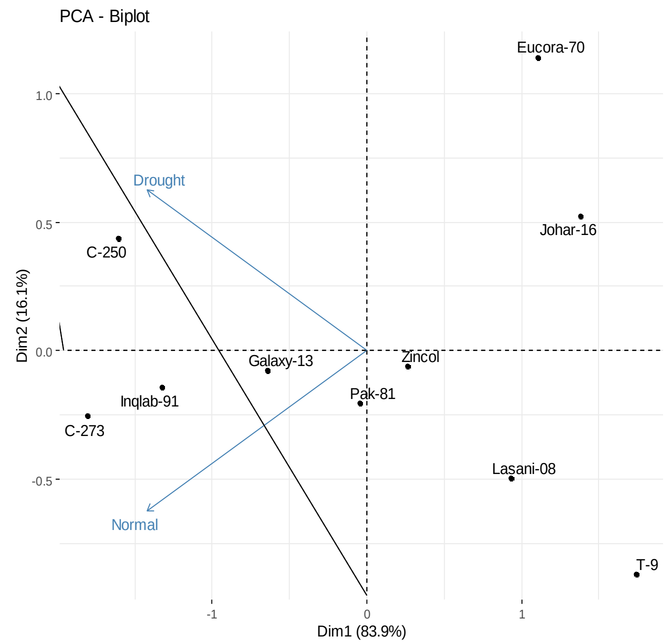

Figure 2 PCA-Biplot analysis of 10 genotypes of wheat under two levels of irrigation for tillers per plant viz. normal and drought

Spike Length

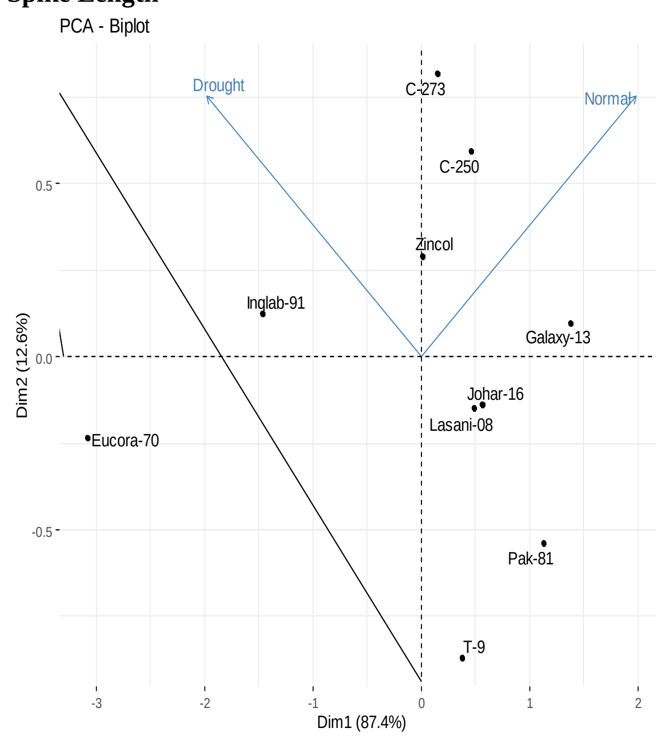

Figure 3 PCA-Biplot analysis of 10 genotypes of wheat under two levels of irrigation for spike length viz. normal and drought

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Peduncle Length

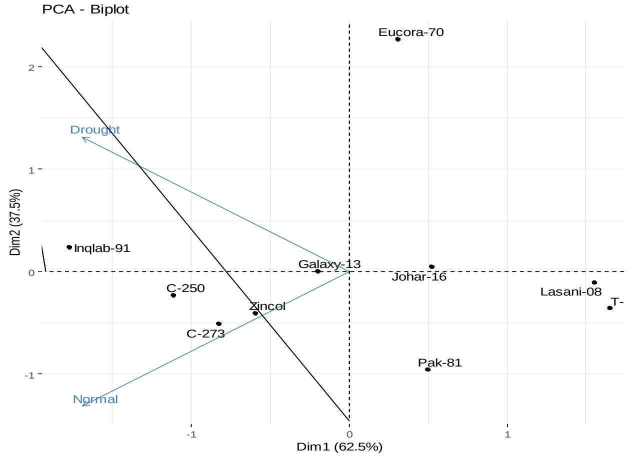

Figure 4 PCA-Biplot analysis of 10 genotypes of wheat under two levels of irrigation for peduncle length viz. normal and drought

Spikelets per Spike

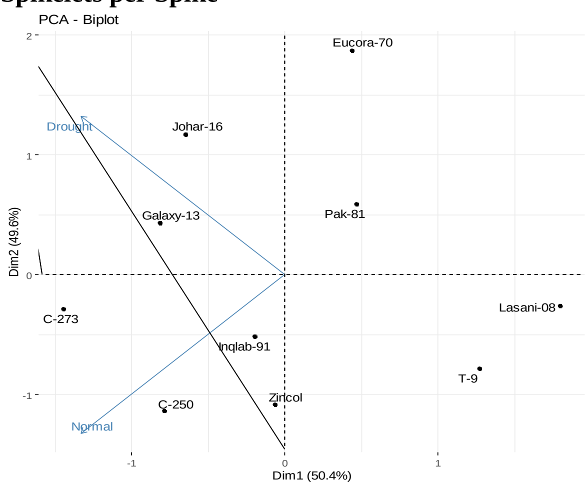

Figure 5 PCA-Biplot analysis of 10 genotypes of wheat under two levels of irrigation for spikelets per spike viz. normal and drought

Number of Grains per Spike

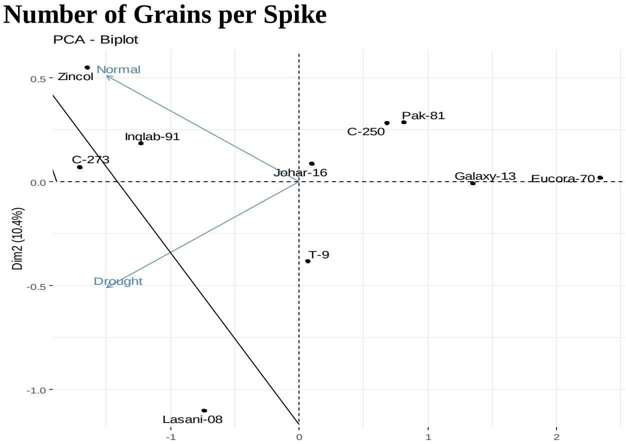

Figure 6 PCA-Biplot analysis of 10 genotypes of wheat under two levels of irrigation for number of grain per spike viz. normal and drought

Yield per Spike

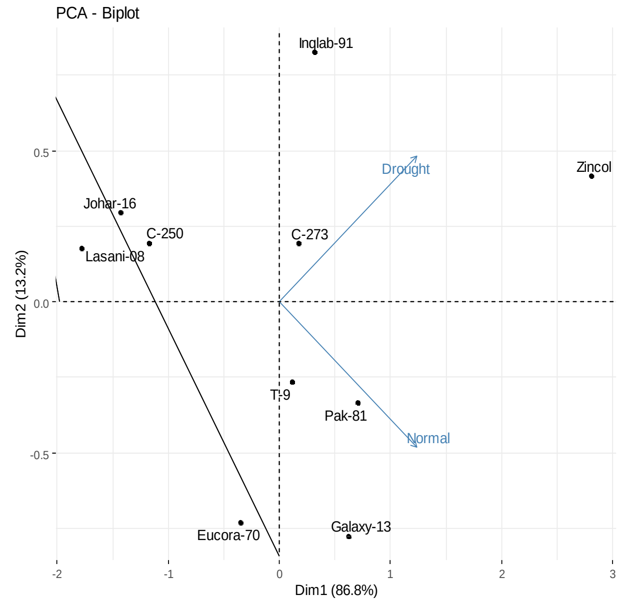

Figure 7 PCA-Biplot analysis of 10 genotypes of wheat under two levels of irrigation for yield per spike viz. normal and drought

Grain Yield per Plant

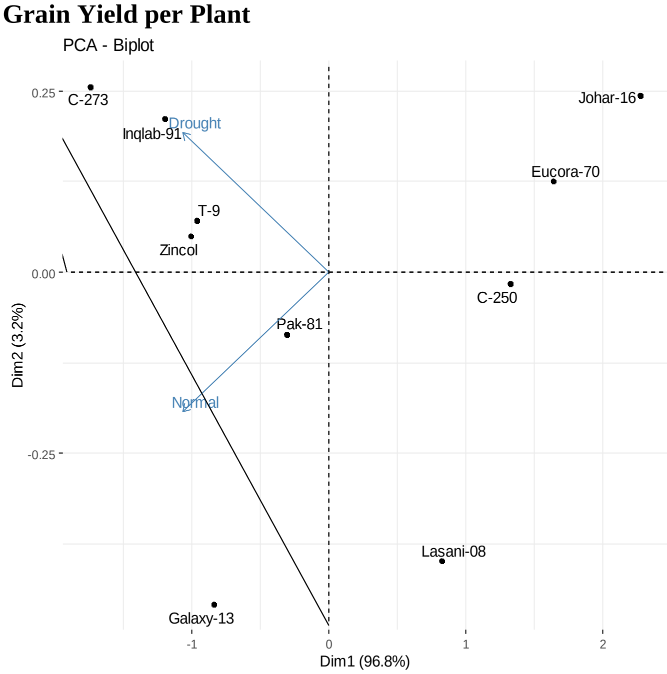

Figure 8 PCA-Biplot analysis of 10 genotypes of wheat under two levels of irrigation for grain yield per plant viz. normal and drought

1000-Grain Weight

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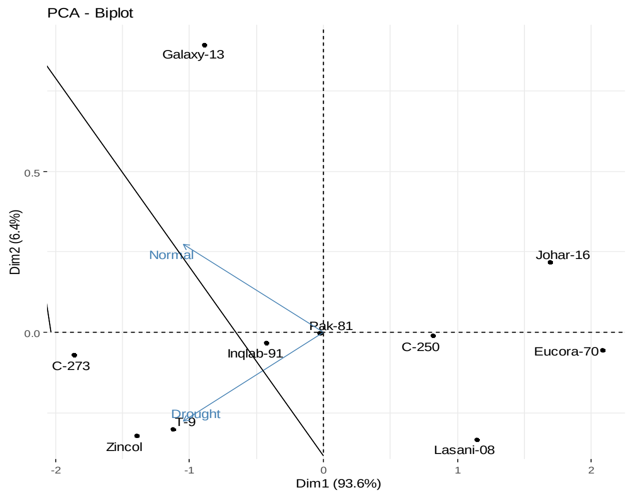

Figure 9 PCA-Biplot analysis of 10 genotypes of wheat under two levels of irrigation for 1000-grain weight viz. normal and drought

PCA-Biplot Analysis for traits under normal irrigation and drought stress:

Data of 10 wheat genotypes was collected from the field experiment for different traits (plant height, number of fertile tillers, spike length, peduncle length) and their mean values were computed. PCA-Biplot analysis was plotted to check the linear relationship of variables having maximum variance and fitness of genotypes in normal and drought conditions. Under normal irrigation zincol, Galaxy-13, and pak-81 showed best performance for yield per spike, Grain yield per Plant and 1000-Grain weight. Plant height was observed maximum for C-273 followed by C-250 and Inqlab-91. Tillers per plant, spikelets per spike, and Grains per plant were observed maximum of Genotypes 7(C-273), 6(C-250), and 1(Inqlab-91). Similar results were found by (Chen et al., 2014; Rasheed and Malik, 2022).

Normal irrigation

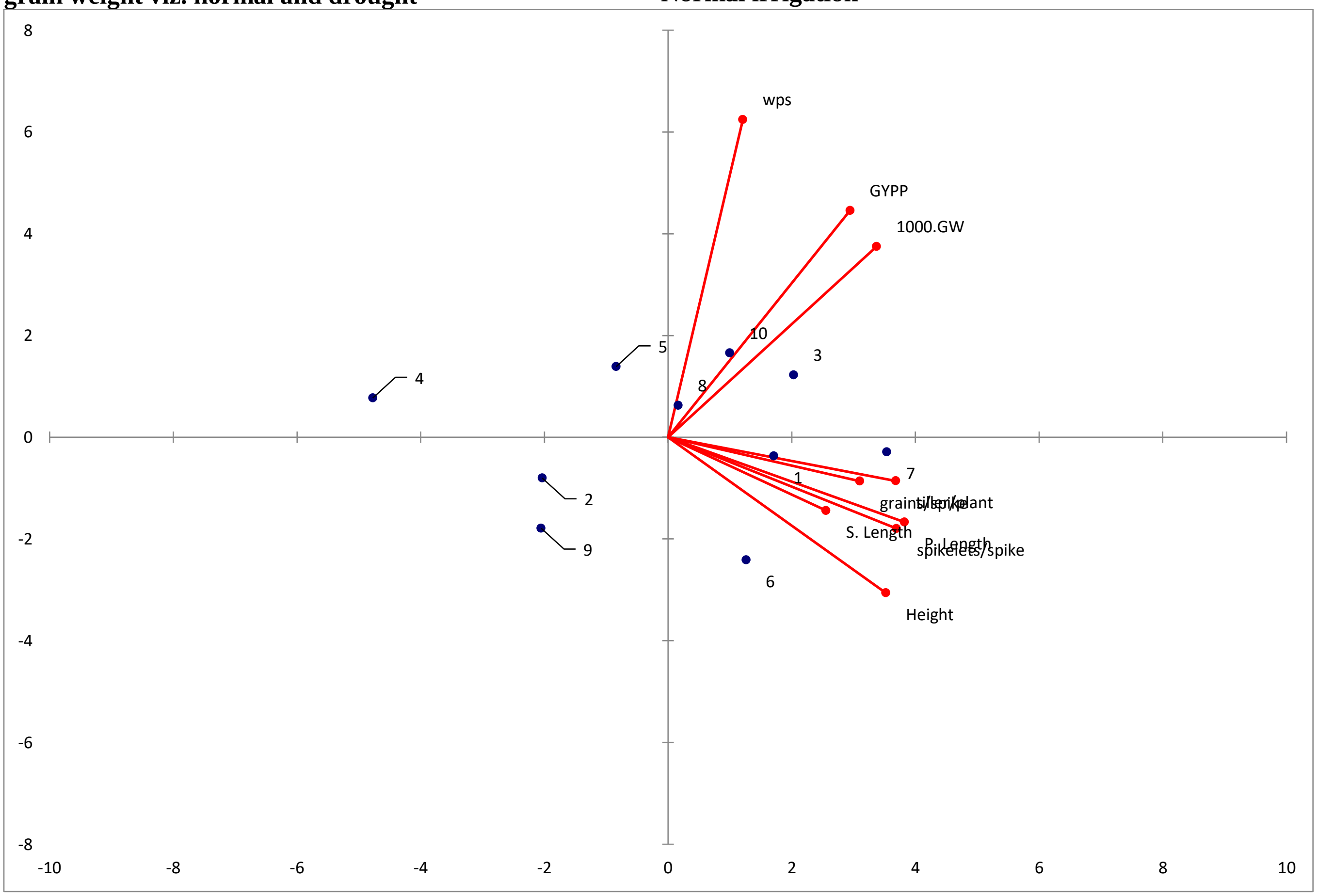

Figure 10 PCA-Biplot analysis of 10 wheat Genotypes under normal irrigation for all taken traits

Under drought stress best performance for 1000-Grain weight was observed in Pak-81 followed by Zincol. Plant height was observed high in Eucora-70. Genotypes C-273 and C-250 were sensitive to drought stress and showed a minimum response. 9 (Johar-16), 5 (T-9) and 2 (Lasani-08) observed better performing genotypes in water stress conditions. Similar results were found by (Lopes et al., 2015).

Drought stress

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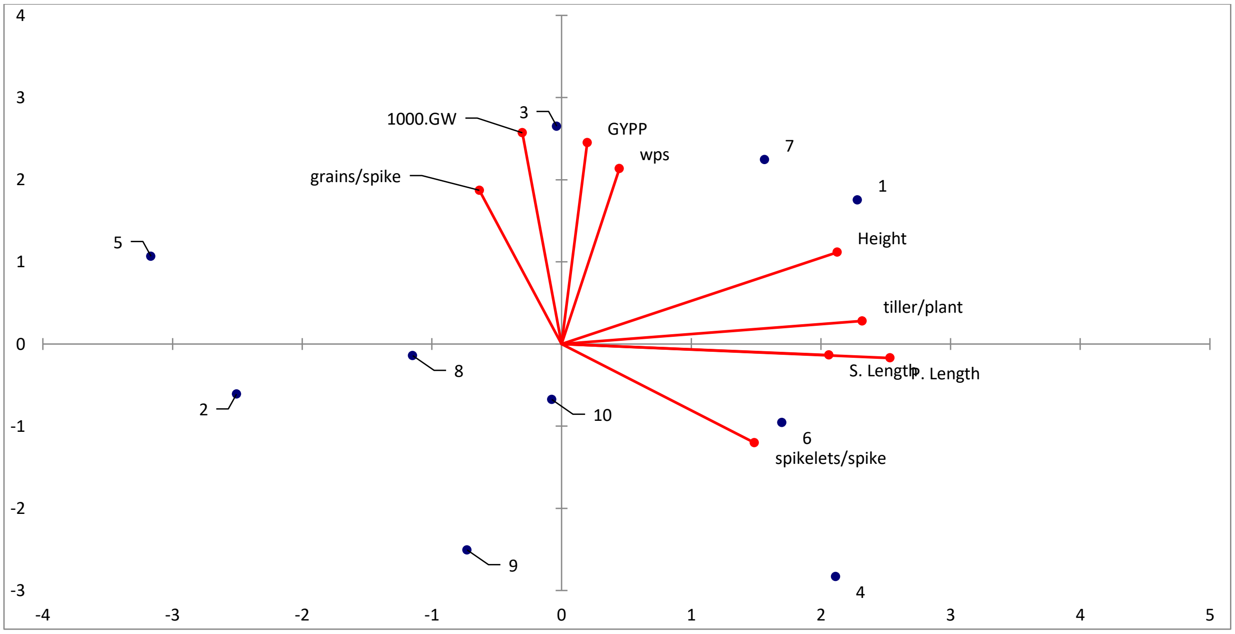

Figure 11 PCA-Biplot analysis of 10 wheat Genotypes under drought stress for all taken traits

Conclusion

Principle component analysis revealed that grain yield is related to 1000-grain weight, fertile tillers per plant, plant height, and plant vigor. The results from PCA-biplot showed the association of wheat yield with days to flowering, chlorophyll content and temperature. The genotypes performed well for these traits can be further used in breeding programs.

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Declaration

Ethics Approval and Consent to Participate

Not applicable.

Consent for Publication

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Conflict of Interest

There is no conflict of interest among the authors regarding this case study.

Authors Contribution

All authors contributed equally.

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