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***Original Research Article***

# GENOTYPIC VARIABILITY & ASSOCIATION STUDIES OF YIELD AND RELATED TRAITS OF WHEAT GROWN UNDER WATER STRESS CONDITIONS

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**Abstract:** *Climate Change is a serious risk to crops as it harnesses the survival of plants and is a major cause for drought stress in many areas of the world including Pakistan. Most of the cultivated area in Pakistan is vulnerable to drought conditions brought about by climate change, leading to fewer productive harvests. Wheat is Pakistan's major staple food crop, but it needs to be enhanced and developed to be more tolerant to drought conditions. We all know that future water crisis would affect us in many ways, and we need plant, which can cope up with water deficiency, otherwise it will be leading grains type of country in near future. To investigate the drought tolerance in wheat, we cultivated fifteen wheat genotypes in a dry and arid region of Layyah under water stress. The plants were irrigated at the initial stages and left them to grow outdoors without irrigation for six weeks. The study's objective was to evaluate these mutants' performance under drought stress. Data were collected for yield and yield-related traits, including plant height, number of tillers, number of spikes, spike length, number of spikelets per spike, grains per spike (each with a part), and grain yield. Underwater, stress conditions, there were significant differences in all the parameters. In the experiment, genotypes Barani-83 and Subhani-21 were drought-tolerant and significantly increased parameters such as the number of grains per spike and grain yield. These parameters can be used as selection criteria for breeding programs of drought-tolerant varieties.*

**Keywords:** climate change, wheat, drought, grain yield, spikelets

## Introduction

Wheat *(Triticum aestivum L.)* has been the most significant food crop in the world since the Neolithic era. It is the second most important staple cereal after rice and is an important source of human nutrition. It provides 20% of the protein in the world. Wheat is the dominant food grain in temperate climates and is widespread in semiarid areas. It is an important source of carbohydrates, the major food source in many areas of the world. Wheat is also grown on a large scale in Japan, Turkey, and the United States of America and is one of the major (Rui et al., 2018; Sallam et al., 2019). Wheat is the most important staple food in the world and is responsible for a significant proportion of the total food intake of the global population. Wheat is cultivated worldwide; the grain is used for the production of breads, pastas, and other bakery products. Wheat is one of the most important food crops in the entire world. It is commonly used to bake bread, which has many uses and purposes beyond just how it tastes. We use wheat in various ways, including during food preparation, cooking and other food flavouring methods. Wheat accounts for 28% of all food produced worldwide that can be consumed by humans (Shewry and Hey, 2015; Tatar et al., 2020). On average, it is grown on more than 220 million hectares annually to produce roughly 750 million tons. Wheat is a staple food for over 35% of the world population. It is cultivated in every environmental condition and is widely versatile, as it grows on rain-fed land and in regions with four seasons. Soft wheat items require less protein than difficult wheat, making them ideal for cultivating. Wheat gives roughly 20% of the nourishment and calories for human consumption worldwide with future food security challenges ahead. In the upcoming years, we expect the global interest in wheat to continue increasing as demand grows significantly more quickly than new developments in yield potential (Aziz et al., 2018). In the Great Plains area, the yearly rate of hereditary addition was approximately 0.44%. Much of this growth can be attributed to characteristics that add to growth in grain number. Because of this, much of hereto forth yield will increase because of more spikes according to area, the variety of seeds according to

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spike and spikelet, and harvest index (generating extra grain from growing yield additives but preserving the identical biomass) (Allard, 1960). With harvest index coming near its theoretical most biologic limits, growing biomass can offer a possibility to growth the photosynthetic tissues for solving carbon and an effective cover to seize radiation power and convert it into dry matter (Vassilva et al., 2011; Nezhadhmadi et al., 2013). The discovery of a new wheat variety can be like hitting the genetic jackpot. Since the 1960s, there has been a significant increase in wheat yield potential and many varieties have contributed to this growth. From 1961-1965, the average wheat yield was 1.18 t/ha; today, that number has risen to 3.15 t/ha. This is an astounding 267% increase! Though there is pretty much no end in sight for growing wheat because plants continue to defy limits every day, we will run into several obstacles along the way as one of these being that humanity does not hold all of the knowledge about how genetics works for increasing crop yields. Selection based on a variety of yield factors as well as crop structure can provide extra avenues for continued growth in yield at the same time as holding off yield plateaus (Bernardo et al., 2019; Karatayev et al., 2022; Zafar et al., 2014). However, relationships among such developments must be taken into account. There are numerous bad correlations between correlated developments, including the well-documented correlation among grain number and mean grain size. The phenotype of an organism can occur both because of genetic composition that is the organism's genotype and its environment. This is a matter of great importance for society as human disorders are phenotypes brought about by disorders in genetics and environment; see for instance the research into schizophrenia (Schizophrenia Working Group of the Psychiatric Genomics Consortium 2014), obesity (Christy et al., 2018; Baloch et al., 2013).

Drought is a polygenically managed pressure and the world's most popular threat that reduces crop productiveness and severely limits the capability of land to grow crops effectively. This issue has been discussed in detail in the following document with an analytical look into how excessive pressure can negatively affect wheat growth. In our first section, it has been explained how there are many ways by which crop plants suffer due to high levels of stress. Below, you will find out about physiological responses on a plant level and changes within cell membranes, leaves, and roots - along with water content that serves as a basis for photosynthesis. Rainfall frequency is affected by high or low temperatures and differing amounts of wind in different regions worldwide (Ali et al., 2016; Ali et al., 2017; Ali et al., 2011ab). Root systems from certain species tend to be more resilient because they have developed defenses against poor environmental conditions such as drought. Osmotic adjustment boosts drought tolerance by letting cells enlarge, the plant to grow, and its stomata to remain partly open. It also preserves cell mass in higher water deficit through preventing $CO_2$ fixation from reaching extreme stages of water loss (Aycicek et al., 2006; Nwadzingeni et al., 2016). The wheat plant accumulates a variety of natural and inorganic ions into its cytosol so that it can be drawn upon when osmotic stress conditions occur, leading to a reduction in overall osmotic ability. Drought negatively affects photosynthesis by affecting internal chloroplast form, mitochondrial heat content, chlorophyll mass, and minerals. Destruction of the photo system II (PSII) oxygen-evolving complex (OEC) and cyclic electron flow around PSI (CEF) can disturb the production and use of electrons, which causes lipid peroxidation and damage to cellular membranes via the creation of reactive oxygen species. Wheat production is difficult to maintain and sustain because of the fluctuations in temperature and drought conditions, which can influence overall yield and quality. For example, fields that suffered from droughts experienced a loss in both their yield weight and in protein quality, making the wheat crop harder for people to use in various recipes. Losses caused by such climate events have been recorded throughout the growing season (Bernardo et al., 2019; Bhargava et al., 2003; Kulkarni et al., 2017). Drought pressures can have long-lasting impacts on plants from their behavior in the early stages of their growth to how they survive drought once fully developed. One way to track these changes is with gene expression, which has been proven effective for various other experiments. When performing such an experiment, environmental elements affecting the plant (water being a key element) mustn't interfere with its genetic makeup. Some plant species may also react differently to extended periods of drought pressure based on how they grow and develop; more specific research needs to be analyzed as we continue our understanding of drought pressure (Puspito et al., 2015; Waseem et al., 2014; Veesar et al., 2007).

**Objective**

- To evaluate the wheat genotypes for productivity in the water stress environment
- To evaluate the genotypic variability and association among yield-related traits in wheat

## Materials and Methods

### Experimental site

The experiment was conducted on agricultural land at the Bahadur sub-campus in Layyah, Pakistan during the 2021-22 wheat seasons. On a sandy loam soil with bulk density of 1.29 Mg, m-3 and pH 8.2 to study how different growing techniques would affect crop growth. The soil at this site was characterized as having medium fertility: nitrogen levels were 435 mg

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kg-1; phosphorus was 6.8 mg kg-1, and potassium was 123 mg kg-1. A set of fifteen genotypes of wheat (BARANI-83, DILKASH-20, PUNJAB-11, Subhani-21, AKBAR-19, AARI-11, GALAXY-13, ANAJ-17,I QBAL2000, SHAFAQ-6, KOHISTAN-97, SANDAL-73, MILLAT-11, UJALA-16, AS-16).The source of genotypes was Ayub Agriculture Research institute of Faisalabad. These fields were located in a category of subtropical climate with warm summers and cold winters with average rainfall between 200 mm - <300 mm per year.

**Plant material & crop management**

Fifteen wheat genotypes were used for the first growing season. Self-sown seeds from previous years were used for the second growing season to obtain enough samples. The seeds were sown during the same dates and in a randomized complete block design (RCBD). A Completely Randomized Design was used, with three replications. Factors included fifteen wheat genotypes, and same dates of sowing after 15 November. This experiment was carried out with a randomized complete block design layout utilizing a RCBD approach. Under this arrangement, the plants were divided into rows that were six feet long, each having 35cm from row to row and plant to plant manually. The five unique types of irrigation were applied based on their timing for pre-sowing irrigation, tillering, joint formation, booting and milking stage. Moreover, fertilizers were added and spread at the recommended rate of 120 kg nitrogen, 90 kg phosphorus and 60 kg potassium per hectare of land. The fertilizers were in the form of urea and calcium ammonium nitrate (CAN) while Buctril super killed weeds at the tillering stage.

**Data collection**

We used the data obtained through scientific experiments, which involved collecting measurements of various traits relating to the plants being studied. These include plant height, the number of tiller/plants, the number of spikelet/spike and spike length.

**Plant height (cm)**

Plant height is taken from the soil of the roots to the end of the awns of the spike with the help of measuring tape by taking the mean of three plants (of one genotype)

**Number of tillers per plant**

The number of tillers was counted by manually of three plants, taking the average number.

**Number of spikelet's/spikes**

The number of spikelets was counted manually in a single plant spike. The average number was then calculated based on three plants**.**

**Spike length (cm)**

The plants were randomly selected to measure the spike length. Spike length was measured from the start of the spike on each plant to its end, excluding awns, and the average of three plants was calculated.

**Grains per spike (g)**

Spikes from the plant were removed and then threshed to yield grains, which were then weighed. These grains were then averaged to form yield per spike.

**Grain yield (grams)**

Three plants from each genotype were threshed individually, and the measured grains were counted to obtain an average yield per plant for each genotype.

**Statistical analysis**

For statistical analysis, we used software Statistix 8.1 to determine the p value by analyzing data using ANOVA. Furthermore, Microsoft excel is used for Path analysis and correlation regression. A graph is made with the features of Microsoft Excel to differentiate how each genotype performs among different parameters.

**Results and discussion**

**Genotypic yield and yield-related traits**

**Plant Height**

Plant height (PH) was significantly different among all genotypes. Plant height of fifteen genotypes under water stress environment ranged from 67 cm to 89 cm.

**Table: 1. ANOVA table for Plant height of wheat under drought stress:**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Replications | 2 | 110.38 | 55.1884 | | |
| Genotypes | 15 | 1071.49 | 71.4325 | 20.46* | 0.0000 |
| Error | 27 | 94.25 | 3.4908 | | |
| Total | 44 | | | | |

**= significant level is ≤0.05, SOV: Source of variance, DF; Degree of freedom, SS: sum of square, MS: mean square

Under water stress highest plant height was in genotype by Millat-11 (88.44) followed by Akbar-19 (88.44), Barani-83 (86.44) and Punjab-11(86.44). While minimum plant height was in genotype shafaq-6 (69.55) followed by Anaj-17(76.33) and Iqbal-2000(78.88). Significant differences were observed among the genotypes when grown in drought conditions in terms of plant height. The decrease in plant height of all genotypes in drought might be due to decreased turgidity, dehydration of protoplasm and loss of relative cell and cell division expansion. Highly significant difference was observed among the plants for transpiration rate (TR) and Net Photosynthesis (N.P.) under normal and stressed conditions due to variations in stomatal density, style differentiation etc., which collectively decreases water consumption by the plant; likewise, it is correlated with nitrogen reduction from the atmosphere which indirectly effects the uptake of $CO_2$

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through photosynthesis (Ali et al., 2010ab; Javed et al., 2016; Hafeez et al., 2021).

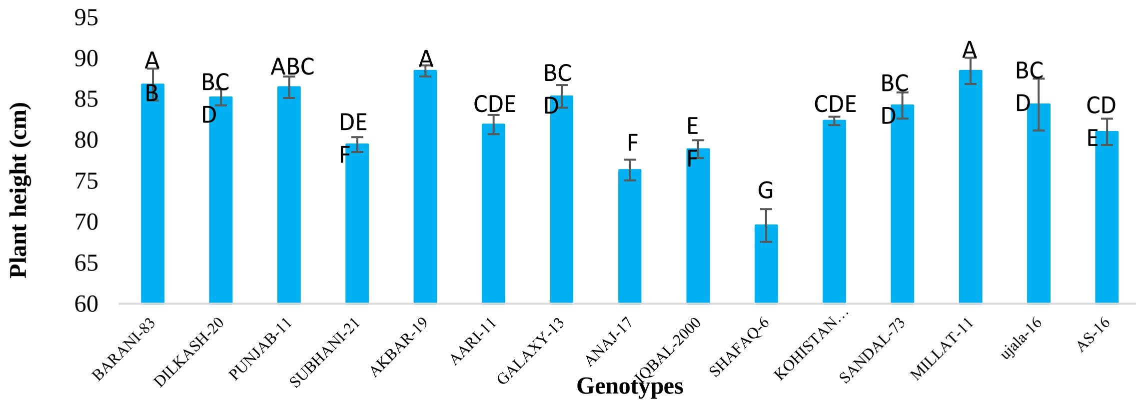


**Figure 1. Comparison of wheat genotypes in water stress for plant height**

Studies have found that drought influences plant height and that plants grown in well-irrigated conditions tend to be taller than those under drought stress. Furthermore, tall genotypes have a greater risk of decreasing yield when exposed to drought conditions than dwarfish varieties. This is important when choosing which varieties are most likely to thrive at your site under specific climatic conditions.

**Number of tillers**

The number of tillers was significantly among all genotypes in water stress environments. Number of tillers of fifteen genotypes in water stress values range from 7.77 to 3.33. Under drought stress highest number of tillers were in genotypes Millat-11 (7.78) followed by Akbar-19 (7.77) and Punjab-11(7.11). While a minimum number of tillers was in genotypes Shafaq-6 (3.22) followed by Galaxy-13 (4.11) and AS-16 (4.33).

**Table: 2. ANOVA table for no of tillers of wheat under drought stress**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Rep | 2 | 0.8685 | 0.43423 | | |
| GEN | 15 | 79.8536 | 5.32358 | 6.49 | 0.0000 |
| Error | 27 | 22.1501 | 0.82037 | | |
| Total | 44 | | | | |

**= significant level is ≤0.05, SOV: Source of variance, DF; Degree of freedom, SS: sum of square, MS: mean square

Number of tillers was highest in genotypes Millat-11(8), Akbar-19 (7) and Punjab-11(7) in water stress condition. In addition, Anova shows that p value of no of tillers was significant under drought stress.

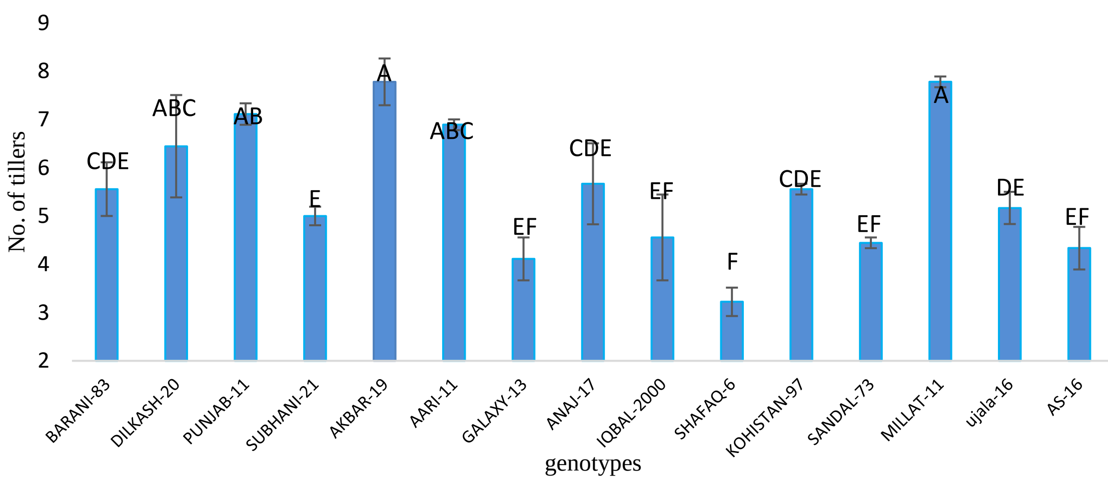


**Figure 2. Comparison of wheat genotypes in water stress for number of tillers**

There was a significant difference in the number of tillers of genotypes in drought stress environments.

**Number of spikes**

ANOVA declared that no spikes was different for genotypes in water stress environments. Number of spikes of fifteen genotypes in drought, stress values range from 19.55 to 17.77. Under drought stress

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highest number of spikes were in genotypes Barani-83 (19.55) followed by Kohistan-97(19) and Subhani-21(18.77). While the minimum number of spikes were in genotypes Shafaq-6(17.8) followed by Galaxy-13 (17.7). Results show maximum reduction in spikes under water stress was experienced in genotype Galaxy-13. While minimum reduction was in genotype Shafaq-6.

**Table: 3. ANOVA table for number of spikes of wheat under drought stress:**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Rep | 2 | 1.2050 | 0.60251 | | |
| GEN | 10.6087 | 0.70725 | 2.53 | | 0.0172 |
| Error | 27 | 7.5357 | 0.27910 | | |
| Total | 44 | | | | |

**= significant level is ≤0.05, SOV: Source of variance, DF; Degree of freedom, SS: sum of square, MS: mean square

It is generally believed that the greater the number of spikelets, the greater the grain yield per plant. This is only true if there is sufficient water at tillering stage. Under water stress conditions, there is a significant decrease in these numbers by 10.98% overall. However, the reduction was greatest for Shafaq-6(17.8), which produces fewer spikelets than its competitors do at tillering stage due to most likely less root growth and, therefore less new grains created overall.

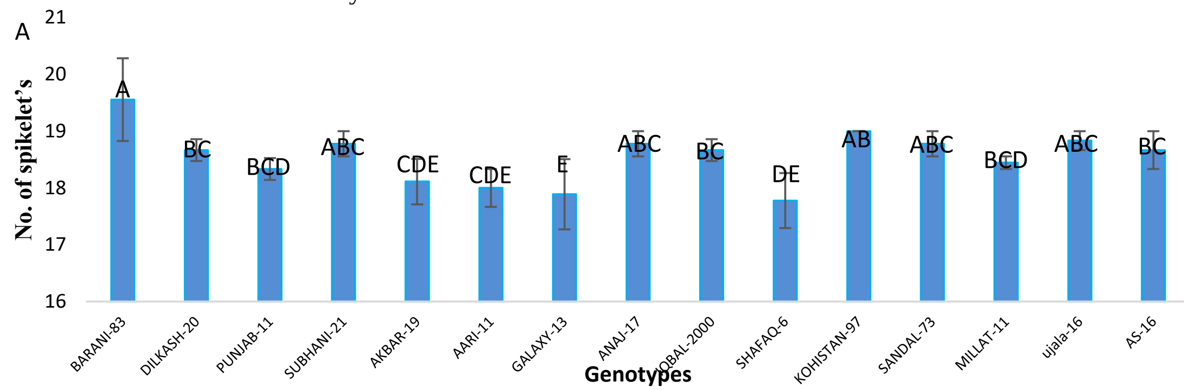


**Figure 3. Comparison of wheat genotypes in water stress for number of spikelet's**

**Spike length**

ANOVA showed that spike length in the experiment differed for genotypes in water stress environments. The length of the 15 genotypes in water stress values ranges from 9.66 cm to 11.88 cm.

**Table: 4. ANOVA table for spike length of wheat under drought stress**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Rep | 2 | 2.1636 | 1.08181 | | |
| GEN | 15 | 16.0016 | 1.06677 | 1.80 | 0.0891 |
| Error | 27 | 15.9975 | 0.59250 | | |
| Total | 44 | | | | |

**= significant level is ≤0.05, SOV: Source of variance, DF; Degree of freedom, SS: sum of square, MS: mean square

In water stress, the spike length of genotype Punjab-11 was highest, i.e., 11.88 followed by Dilkash-20 (11.11) and 16(10.88). While the spike length of genotype was minimum in the water stress of Ujala-16 (9.66) followed by Sandal-73 (9.88) and Millat-11 (10).

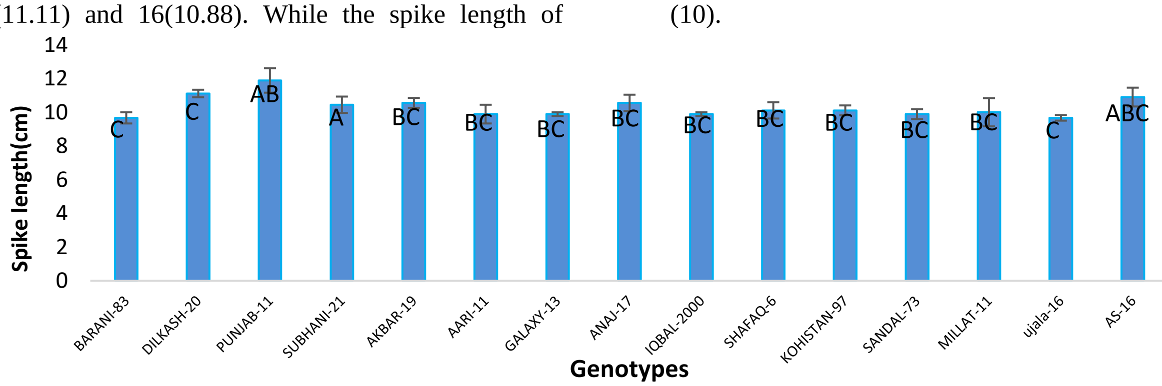


**Figure 4. Comparison of wheat genotypes in water stress of spike length**

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**Grains per spike (g)**

ANOVA showed that Grains per spike in the experiment were different for genotypes in water stress environment. Grains per spike of 15 genotypes in water stress value ranges from 32.73 g to 18.69g.

**Table: 5. ANOVA table for grains/spike of wheat under drought stress**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Rep | 2 | 0.78 | 0.3914 | | |
| GEN | 15 | 1084.34 | 72.2895 | 27.07 | 0.0000 |
| Error | 27 | 72.12 | 2.6709 | | |
| Total | 44 | | | | |

**= significant level is ≤0.05, SOV: Source of variance, DF; Degree of freedom, SS: sum of square, MS: mean square

In water stress Grains per spike of genotype Barani-83 was highest i.e., 32.73 followed by Galaxy-13 (32.66) and Ujala-16(32.08). While Grains per spike of genotype was lowest in water stress of Punjab-11 (18.69) followed by Anaj-17 (19.52) and Kohistan-97 (21.98).

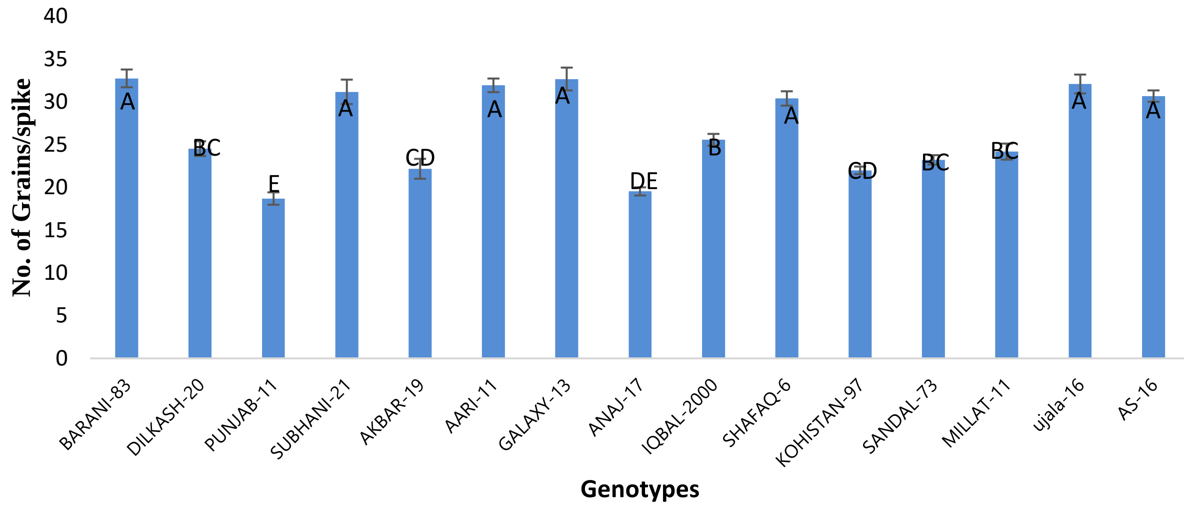


**Figure 5. Comparison of wheat genotypes in water stress for No. of Grains/spike**

Due to the low air temperature and high air or soil temperature, the numbers of spikes or tillers per meter squared reduce. Because of delayed emergence due to low temperatures and early maturation due to high temperatures, particularly during grain filling, this causes fewer spikes or tillers each plant per meter squared. Stress is caused when drought kills sterile pollen. Pollination is not taking place; this stops the current photosynthesis and causes slow transfer of any stored food material. This will reduce the number of spikelets in grains and finally low harvest numbers (Ali et al., 2013; Akeura, 2009; Ali and Ahsan, 2012).

**Grain yield (g)**

Grain yield (GY) was significantly different among all genotypes. Grain yield of 15 genotypes under water stress environment ranged from10 g to 4 g.

**Table: 6. ANOVA table for grains yield of wheat under drought stress**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Rep | 2 | 0.5976 | 0.29881 | | |
| GEN | 15 | 77.9310 | 5.19540 | 17.38 | 0.0000 |
| Error | 27 | 8.0690 | 0.29885 | | |
| Total | 44 | | | | |

**= significant level is ≤0.05, SOV: Source of variance, DF; Degree of freedom, SS: sum of square, MS: mean square

Under water stress, highest yield was in genotype by Barani-83(10) followed bysubhani-21 (9), Dilkash-20 (8.66) and Aari-11 (8). While lowest yield was in genotype. Punjab-11 (4) followed by Anaj-17(16) and Akbar-19 and AS-16 (7.66). Anova showed that the p value of wheat grain yield under water stress was significant. Many researchers' Greater grain yield has reported decreased grain yield under drought condition was observed in irrigation conditions than drought and heat stress environment. This was because of more spikes per square meter, heavier grains, and a longer plant cycle. No significant reduction in grain yield may result from post anthesis water stress because of the source limitation, power of sink to absorb photo-assimilates, and grain filling duration (Aaliya et al., 2016; Abbas et al., 2015; Abbas et al., 2016; Naveed et al., 2012).

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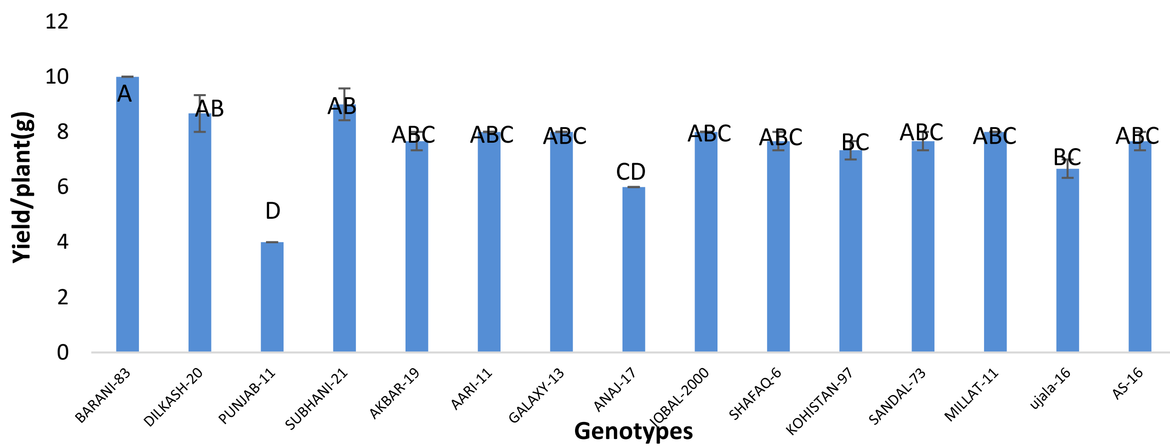


**Figure: 6. Comparison of wheat genotypes in water stress for yield/plant**

Drought stress delays development decreases the number of grains per spike and grain weight and increases the grain protein level. The improvement of cultivar yield under drought stress condition has resulted from a prolonged grain-filling period, high chlorophyll content, a more sustained turgor or combination of them. Wheat is an important cereal crop but is severely affected by abiotic stress. Drought is a major factor that limits its production. To overcome the effects of climate changes and environmental intolerances, we need drought-tolerant high-yield wheat cultivars that are well suited to fulfill the increasing requirements of our rapidly growing world population. Drought-Tolerant produced fewer grains per spike; had a smaller number of spikelets per spike but showed higher grain weight and, thus, grain yield than other genotypes. Barani-83 and Subhani-21 were Drought-Tolerant genotypes that may be recommended in breeding programs to increase drought tolerance (Aaliya et al., 2016; Abbas et al., 2015; Abbas et al., 2016; Ahmad et al., 2012; Pequeno et al., 2021).

**Conflict of interest**

The authors declared absence of conflict of interest.

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