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Research Article

SCREENING OF DIFFERENT WHEAT VARIETIES UNDER RAINFED CONDITIONS

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Abstract

Triticum Aestivum L. is a major cereal crop grown worldwide. Wheat is staple diet for billions of people and animals feed in all over the world. This study used yield trial data from various sources to evaluate wheat cultivars under rainfed conditions. wheat has sown 1st October to 1St December. The study examined 10 wheat cultivars from three locations in one season. Some cultivars yielded consistently high across locations and seasons, while others yielded differently. The analysis also showed that soil type, sowing time, and cropping season weather affected cultivar yield performance. The study emphasizes the importance of choosing wheat cultivars that suit rainfed conditions and sowing time. RCBD design and three replications were used in this experiment. Different parameters were collected such as days to heading, days to maturity, number of tillers, no. of spikelet per spike, plant height, germination percentage, yield g/plot, and disease rust data in rainfed conditions. Randomized Complete Block design and LSD test were used for this experiment. Total 25 wheat genotypes were sown under rainfed conditions. 10 varieties perform better production under rainfed conditions. These varieties like Barani-17, Ehsan-16, Fakhar e Bhakkar, Bhakkar Star and Zincol, Akbar-19, Ujala-16, Inqlab-91, Anaj-17, Attock-19, and Ghazi-19 show better perform under rainfed condition. The findings can help wheat growers, seed companies, and policymakers choose the best rainfed wheat cultivars to boost wheat yields and food security.

Keywords: *Triticum Aestivum L., Drought Stress, Wheat Yield, Rain-fed, Cultivar*
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1. INTRODUCTION

Triticum aestivum L. has 42 chromosomes, the common name of wheat is Gandum. Wheat belongs to Poaceae or Gramineae. The first time wheat was originated 10,000 years ago in southeast Turkey. The modern wheat Triticum aestivum crop is the staple food all over the world. Wheat is a hexaploid crop. 8.7% value addition of wheat contributed in Pakistan's agriculture and Pakistan's GDP increased 1.7%. The total yield of wheat was 24946 kg/ha in a total cultivated area of 8,825 thousand hectares (2019-20). During 2019-20, total wheat production in Punjab was 19402000 kg/ha.

Wheat has three genomes like A, B & D such as 1st is Triticum monococum 2n=14 has genome AA, 2nd is Triticum turgidum 2n = 28 has genome AABB, 3rd is Triticum tauschii 2n = 14 has genome DD (Anders et al., 2021).

The population of the world is increasing day by day. The agricultural land is also decreasing due to the increasing population. The wheat is the most consumable crop in the world. About 70% of the world's wheat is cultivated under the rain-fed conditions without any irrigation. The productivity of the crop is critically decreased because of the arid conditions. The yield losses may reach up to 70% in various areas of the World. In Pakistan, the wheat under rain-fed conditions in the Potohar region is cultivated on 20% of the total wheat cultivation. The normal yield in the arid region is 50% less than the yield of the irrigated areas.

Rainfed wheat yield trials are crucial to agricultural research and practice. Rainfed wheat assessments can help researchers produce drought-tolerant wheat cultivars by identifying strains that are water-resistant. In locations with little or inconsistent irrigation, this research can help grow rainfed wheat cultivars, improving food security and agricultural sustainability. Understanding how different wheat varieties perform under rainfed settings helps agriculture adapt to climate change by showing which cultivars can better resist changing weather patterns. Asia, wheat has become a staple food for many masses worldwide, ranking third in importance behind rice and maize. Wheat (*Triticum aestivum L.*), which nutritionally is the most dense grain, is also considered the most marketed crop in the marketing industry. It meets the dietary needs of a large part of the global population consuming ¼ of the total annual caloric intake and ½ of total carbohydrate intake (Haroon et al., 2021).

1.1. Drought Stress on Wheat

Drought is a phenomenon that arises when human water usage exceeds the capacity of natural water reservoirs (JAFAR et al.2017). The occurrence of drought stress differs in that it's due to some of the following reasons like instance, global warming, which can be tackled by altering the length, frequency, pattern, the intensity of rain, and during the different developmental phases of a plant (Juroszek et al., 2013 & Khaeim et al., 2022). The extent of the losses caused by drought is way higher than the total losses caused by all the other biotic and abiotic stresses (Khakwani et al., 2012).

Morphological traits include early senescence, lower plant height, a short vegetative life span, and an elevated harvest index are promising and dependable symptoms for drought stress wheat improvements (Pour-Aboughadareh, 2020). Drought stress has affected 32-39 million hectares of wheat fields, leading to severe output losses during planned plant growth stages (Maqsood et al., 2012). The most vulnerable parts of the wheat plant to drought stress are the booting and grain-filling stages, which cause a decrease in the number of spikes, the number of grains per spike, and the size of the grains (Mirzaei et al., 2011). Pakistan's wheat area experiences very unpredictable rainfall, which makes it difficult to cultivate (Monneveux et al., 2012).

Drought has impacted wheat crops more than any other abiotic factor in terms of potential productivity (Wassmann et al., 2009). To prevent the harmful effects of drought stress, wheat crops evolved and modified internal systems to complete their life cycle before stress began (Farooq et al., 2012). This stress hampered crop growth and resulted in massive yield losses, which is a substantial contributor to low yield (Farooq et al., 2009). For current plant breeders and plant researchers worldwide, maintaining sustainable production and a progressive increase in yield while taking future food security issues into account has become a difficult task (Chaves et al., 2013).

1.2. Crop Growth and Yield of Wheat

Water shortage cuts down the growth and yield of crops in the context of retrenchment in turgor pressure which triggers an undermined germination rate along with an impoverished stand of the wheat plant and provokes the deferred implantation of enduring root setup (Razzaq et al., 2016). The reduction of time period also affects negatively during anthesis and grain-filling stages whose consequences are revealed in the form of

Table 1 Details of Genotypes, Origin and Taxonomy

Genotypes	Variety Code	Variety Name	Origin	Taxonomy
1	20C1	Bhakkar Star and Zincol	Pakistan	*Triticum Aestivum L.*
2	20C2	Ghazi-19	Pakistan	*Triticum Aestivum L.*
3	20C3	Faislabad -08	Pakistan	*Triticum Aestivum L.*
4	20C4	Wafaq-2001	Pakistan	*Triticum Aestivum L.*
5	20C5	Fakhar e Bhakkar	Pakistan	*Triticum Aestivum L.*
6	20C6	Borlaug-16	Pakistan	*Triticum Aestivum L.*
7	20C7		Pakistan	*Triticum Aestivum L.*
8	20C8	Pakistan-13	Pakistan	*Triticum Aestivum L.*
9	20C9	NARC-11	Pakistan	*Triticum Aestivum L.*
10	20C10	Akbar-19	Pakistan	*Triticum Aestivum L.*
11	20C11	Markaz-19	Pakistan	*Triticum Aestivum L.*
12	20C12	Jauhar-16	Pakistan	*Triticum Aestivum L.*
13	20C13	Ujala-16	Pakistan	*Triticum Aestivum L.*
14	20C14	Nwab 21	Pakistan	*Triticum Aestivum L.*
15	20C15	Ehsan-16	Pakistan	*Triticum Aestivum L.*
16	20C16	Attock-19	Pakistan	*Triticum Aestivum L.*
17	20C17	AAS-11	Pakistan	*Triticum Aestivum L.*
18	20C18	Fateh Jang-16	Pakistan	*Triticum Aestivum L.*
19	20C19	Sadiq 21	Pakistan	*Triticum Aestivum L.*
20	20C20	Anaj-17	Pakistan	*Triticum Aestivum L.*
21	20C21	Sehar-2006	Pakistan	*Triticum Aestivum L.*
22	20C22	Inqlab 91	Pakistan	*Triticum Aestivum L.*
23	20C23	Barani-17	Pakistan	*Triticum Aestivum L.*
24	20C24	Millet-11	Pakistan	*Triticum Aestivum L.*
25	20C25	Fateh jhang-16	Pakistan	*Triticum Aestivum L.*

infecundity followed by shriveled grain-filling and kernel-formation (Odiyo, 2013).

2. Materials and Methods

2.1. Plant Material

In this study, two international wheat yield trials and one national yield trials of wheat were carried out under the rain-fed conditions to check their productivity and select the best-performing lines from these trials. The experiments were planted with the Randomization Complete Block Design (RCBD). The field and the location of the trials was BARANI Agriculture Research Institute Chakwal, Punjab, Pakistan (32.9328° N, 72.8630° E).The trials named as Semi-Arid Wheat Yield Trial (SAWYT) and Elite Spring Wheat Yield Trial (ESWYT) were from the International Maize and Wheat Improvement Center (CIMMYT). Similarly, the National Regional Yield Trial (NRYT) were from the National trials for the selection of lines in the development of the variety. All of the three trials were sown on November 1. 2020. RCBD design, three replications, and one treatment were used in this experiment. 25 genotypes were sown in rainfed conditions, the weather condition of a semi-arid climate are hot in summer and chilly in winter. Its soil has Sandy loamy. The climate is subtropical, with dry weather and an average annual rainfall of 250-500 mm, primarily during the monsoon. The trials were managed all along the season and different traits were collected from these trails for the evaluation of the best performing lines.

2.2. Recorded Observation

a) The following observation were recorded at the maturity stage. These parametersare given below Days to heading

b) Days to maturity

c) No. of tillers

d) No. of spikelet per spike

e) Plant height cm

f) Germination percentage

g) Yield g/plot

2.3. Disease (Rust) Data Collection

Yellow Rust is the major disease affecting the wheat crop. In this disease, the yellow streaks and spores are visible on the leaves of the wheat plant. The rust attacks the leaves and affects photosynthesis that will in turn affect the yield of plant. Stripe (yellow) Rust is primarily beneficial in chilly climates with low temperatures and is brought on by the basidiomycete fungus Puccinia striformis (Shafi et al., 2022). Bright yellow to orange urediniospores with a diameter of 20 to 30 um are produced by the fungus. These spores are found in pustules on the plant and have thick, echinulated walls (Chen et al., 2014). Late in the season, teliospore production typically occurs after uredinio sporese production. Alternative hosts are not known. In milder regions, the pathogen persists in wheat as latent mycelium (Kolmer et al., 2009).

In the trials, Morocco lines were used as the spreader for the rust disease (Asghar, 2022). The lines were planted after every 10 genotypes of the trials. These lines have the most attack of rust on them and can be termed as spreader lines that help in spreading the disease. By planting the spreader lines into the trials, we can easily expose the trials to rust and study the effect of rust on the trials afterwards.

In the rust data collection, we verify the attack of rust on the leaves and then give the entry a score. This score is based on the percentage of attacks of Rust.

a) Susceptible (S)

b) Resistant (R)

c) Moderately Resistant (MR)

d) Moderately Susceptible (MS)

e) Moderately Resistant Moderately Susceptible (MRMS)

For example, we are studying the rust attack on a line, we will examine the total area of leaves under the rust attack and the response of the plants to the rust attack. If the attack on leave parts is only 10% of the total leave area and the spores are also forming on the leaf, then we will give a score of 10MR to it which means that 10% of the leaf is being affected and the plant is showing moderate resistance.

2.4. Management practices of the trials

The management of the trials is very important as the trials if destroyed can affect the whole research.

2.5. Rouging

The rouging in the wheat yield trials is very important. In rouging, the off-type or mixture plants in an entry are removed from the plots. This has to be done to avoid the seed mixture at the harvesting stage. The plants with different heights and which are not uniform are removed from the plots by pulling them along with the roots. The spikes of these mixture plants are also different upon observing them closely (Rosell et al., 2013).

2.6. Rechecking of Selected Lines

The lines that were selected while giving the agronomic score had to be rechecked. The rechecking is done to ensure that the score that is given to the genotypes is also in accordance with the performance of that entry in the trial (Sieber et al., 2014).

2.7. Tillers/m^2

The tillers of the wheat in a meter square were counted to check the plant density and the no. of tillers emerging from the single seed (Masle, 1985). The counting of

Table 02. Mean square and coefficient of variation values for different morphological traits of ESWYT wheat genotypes

Source	PH	DH	DM	Germi%	Yield
Rep	**22.3333**	**10.72**	**0.41333**	**25**	**71483**
Genotypes	**74.0833**	****19.5978**	**4.84667**	****73.8333**	****945147**
Error	**19.2083**	**9.4978**	**5.78833**	**17.7083**	**40606**
CV%	**5.46**	**2.6**	**1.56**	**5.27**	**7.82**

tillers helps in analyzing that which line has the most number of tillers and has high plant density than the others.

A "m2" area is marked randomly in the entry plot where the wheat trial is planted. After marking the area, the tillers are counted manually with the hands.

2.8. Spikelet/spike and spike length

The number of spikelets in spike vary according to different wheat varieties. The spikelet when counted from one side in a spike should be in between 8-12 spikelet.

Random spikes are selected from the entry plots of the trials and the spike length is measured with the help of measuring tape (Sharma et al., 2003). This helps us to analyze the height of the spike from the total height of the wheat plant later on when the plant height is measured.

2.9. Agronomic Score

Agronomic Score is the number which we give to the entry of the wheat trial according to their performance. We give the agronomic score on the basis of plant phenotypic characteristics and the resistance of the plants against the rust attack.

Giving score from 1-5 to the lines

a) 1 number is Poor

b) 5 number is Excellent

The highest best-performing score is 5. This score is given to the line which performs best in all the phenotypic scenarios like disease resistance, uniformity of the plants in an entry, moderate plant height, plant vigour, spike length, spike thickness and early maturity characteristics of the entry in the wheat trials.

The entry in the wheat trials with excellent or good agronomic scores is selected for the next yield trials.

2.10. Statistical Analysis

Software Statistix10 trial analyzes data. At 0.05 significance level using LSD, data are significantly different when letters are different (Leilah et al., 2005).

3. Results:

Table 03 Mean square and coefficient of variation values for different morphological traits of SAWYT wheat genotypes

Character	Rep	Genotypes	Error	CV%
SAWYT Yield	44616	**905008	22644	5.58

Table 04. Mean Square and Coefficient of Variation Values for Different Morphological traits of NRYT Wheat Genotypes

Character	Rep	Genotypes	Error	CV%
NRYT Yield	27227	**453283	16883	3.99

ESWYT (**Table 02.**) =Elite spring wheat yield trial, PH = plant height, DH = days of the heading of plants, DM = days of maturity of plants, GERM% = germination percentage of wheat, YIELD = yield of elite semi-arid wheat yield trials, SAWYT (**Table 03.**) = semi-arid wheat yield trial, NRYT = (**Table 04.**) National Regional Yield Trial.

3.1. Elite Spring Wheat Yield Trial (ESWYT) BARI 2020-21

3.1.1. Plant height

Analysis of variance for plant height (ph) showed a significant difference at the 5% level of genotypes. Covariance of variation (C.V) for plant height was 5.46% (Table 2). Plant height from 73.33-83 cm, maximum plant height was recorded in genotypes no. 18, 19, 22&5 while lowest plant height was recorded in genotypes no. 20, 8 &3 (Table 05). Plant height 5.46% is highly significant (Table 2). These traits are highly significant and shows variation.

3.2. Days to Heading of Elite Spring Wheat Yield Trial

Analysis of variance for days to heading (DH) showed significant difference at the 5% level of genotypes (Table .02). Covariance of variation (C.V) for days to heading was 2.6% (Table 2). Days to heading from 116.33-121.33 maximum days to heading was recorded in genotypes no. 23, 19, 24 & 2 while minimum days to heading was recorded in genotypes no. 14, 16 & 20 (Table 05). Days to heading 2.6% is highly significant (Table 2). These traits are significant and shows variation.

the 5% level of genotypes (table .2). Covariance of variation (C.V) for days to maturity was 1.56% (Table 2). Days to maturity from 152.33-155.33. Maximum days to maturity were recorded in

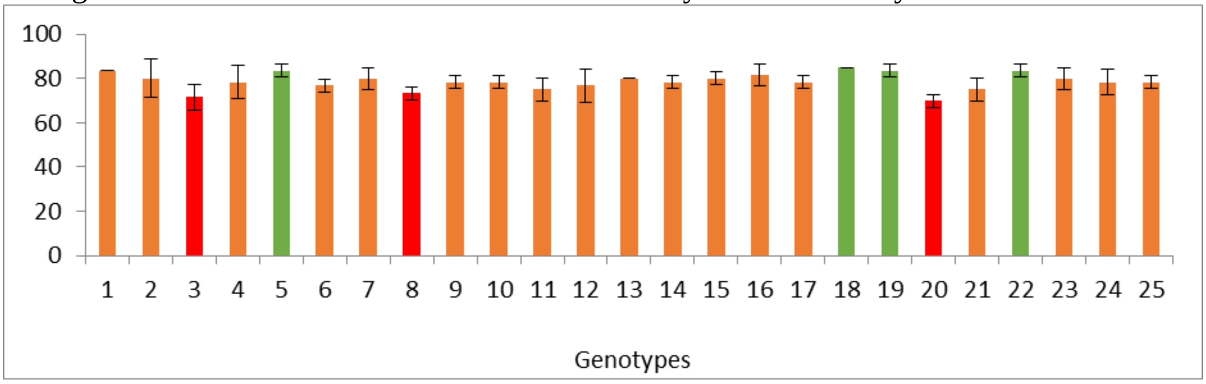

Figure 01. Maximum plant height was recorded in genotypes no. 18, 19, 22&5 while minimum plant height was recorded in genotypes no. 20,8 3. Plant height 5.6% is highly significant. These traits are highly significant and shows variation.

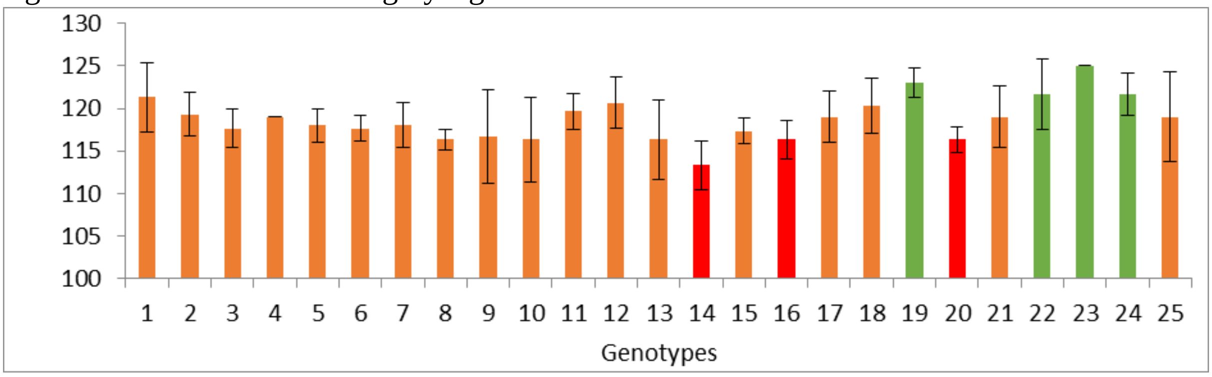

Figure 02. maximum days to heading was recorded in genotypes no. 23,19&24 while minimum days to heading were recorded in genotype no. 14&10. Days to heading 2.60% is highly significant. These traits are significant and show variation.

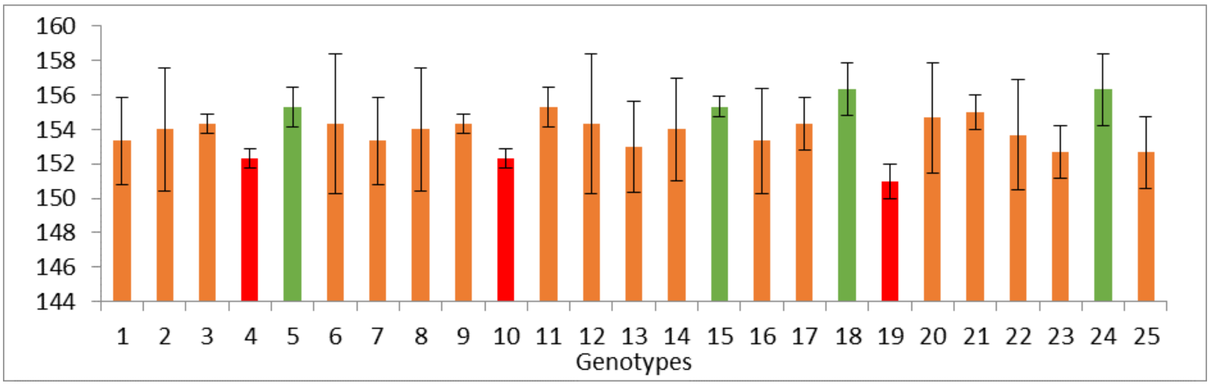

Figure 03. Maximum days to maturity were recorded in genotypes no. 24,18,5& 15 while minimum days to maturity were recorded in genotypes no.10,4&20. days to maturity 1.56% is highly significant. These traits are highly significant and show variation.

3.3. Days to Maturity of Elite Spring Wheat Yield Trial

Analysis of variance for days to maturity (DM)) showed a significant difference at

genotypes no. 24,18,5& 15 while minimum days to maturity were recorded in genotypes no.10,4 &20 in Table 05. days to maturity 1.56% is highly significant. These traits are highly significant and show variation.

3.4. Germination of Elite Spring Wheat Yield Trial

Analysis of variance for germination growth (GM) showed significant difference at the 5% level of genotypes (table .2). Covariance of variation (C.V) for germination growth was 5.27% (Table 2). Days to maturity from 83.333-73.33. Maximum germination growth was recorded in genotypes no. 18, 8, 14 &2 while minimum days to maturity was recorded in genotypes no. 7, 12 &13 (Table 05). Days to maturity 5.27% is significant. These traits are significant and show variation.

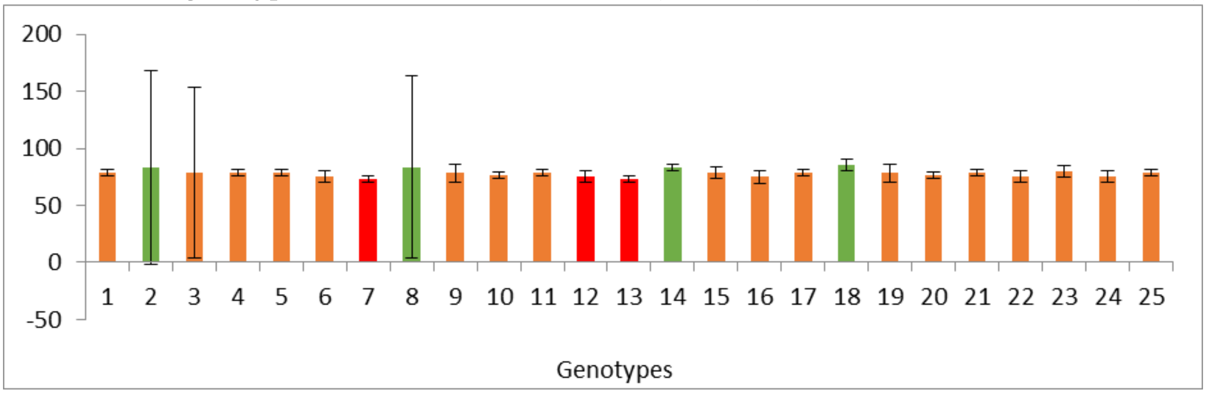

Figure 04. Maximum germination growth was recorded in genotypes no. 18, 8,14 &2 while minimum days to maturity was recorded in genotypes no.7,12 &13. Days to maturity 5.58% is significant. These traits are significant and show variation.

3.5. Yield kg/plot

Analysis of variance for yield production showed significant difference at the 5% level of genotypes (table .2). Covariance of variation (C.V) for yield was 7.82% (Table 2). Yield production from 1895.3-3310.7. Maximum yield production was recorded in genotypes no. 20, 16, 15 & 2 while minimum yield production was recorded in genotypes no. 4, 13 & 7(Table 05). Yield 7.82% is significant. These traits are significant and show variation.

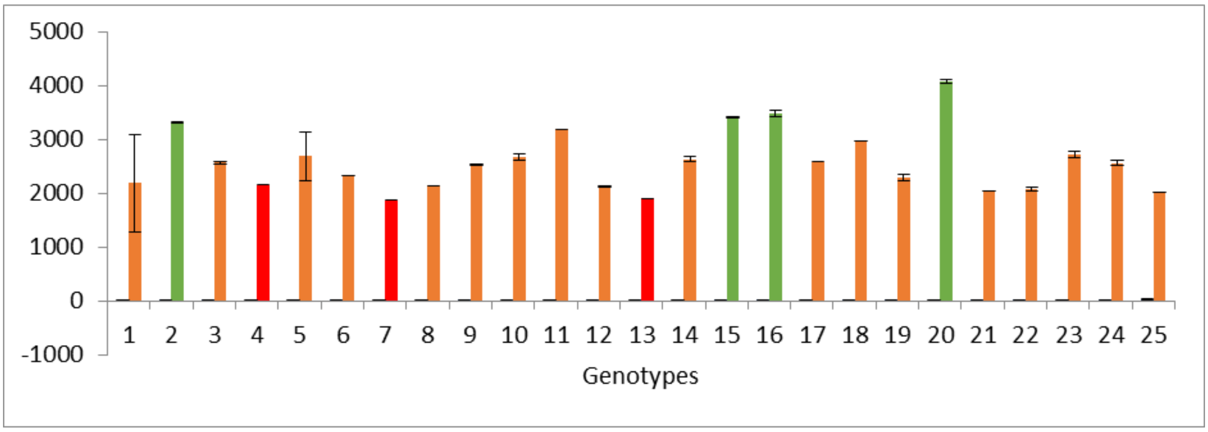

Figure 05. Maximum yield production was recorded in genotypes no20, 16,15 &2 while minimum yield production was recorded in genotypes no. 4, 13 & 7. Yield 7.82% is significant. These traits are significant and show variation.

3.6. National Regional Yield Trial (NRYT) BARI 2020-21

Yield kg/plot: Analysis of variance for yield production showed significant difference at the 5% level of genotypes (table 4). Covariance of variation (C.V) for yield was 3.99% (Table 2). Yield production from 2521.7-3833.3. Maximum yield production was recorded in genotypes no. 1, 10, 13 & 22 while minimum yield production was recorded in genotypes no. 2, 4 & 17 in table 05.

Yield 4.63% is significant. These traits are significant and show variation.

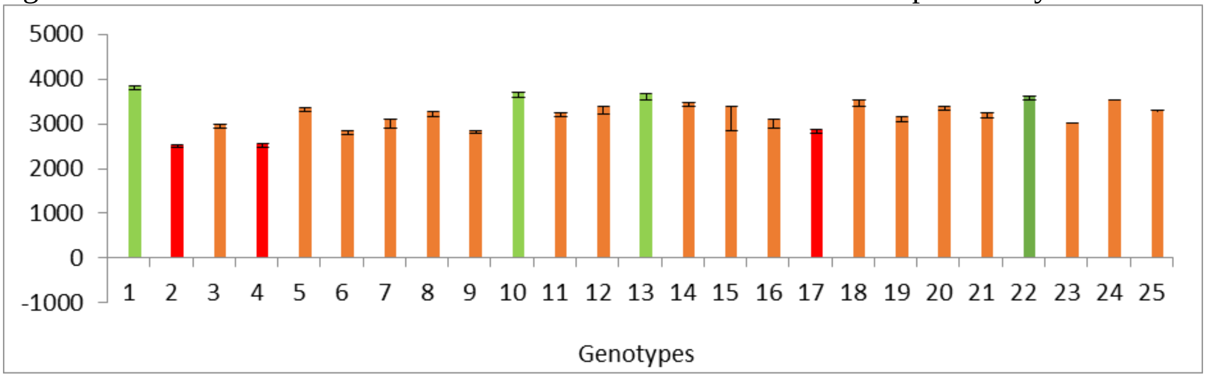

Figure 06. Maximum yield production was recorded in genotypes no. 1,10,13&22 while minimum yield production was recorded in genotypes no. 2,4&17. Yield 4.63% is significant. These traits are significant and show variation.

3.7. Semi-Arid Wheat Yield Trial (SAWYT) BARI 2020-21

Yield kg/plot: Analysis of variance for yield production showed significant difference at the 5% level of genotypes (table 3). Covariance of variation (C.V) for yield was 5.58% (Table 2). Yield production from 1732.0 – 3310.0. Maximum yield production was recorded in genotypes no. 23, 15, 14 & 5 while minimum yield production was recorded in genotypes no. 12, 21 &11 (Table 05). yield 5.60 % is significant. These traits are significant and show variation.

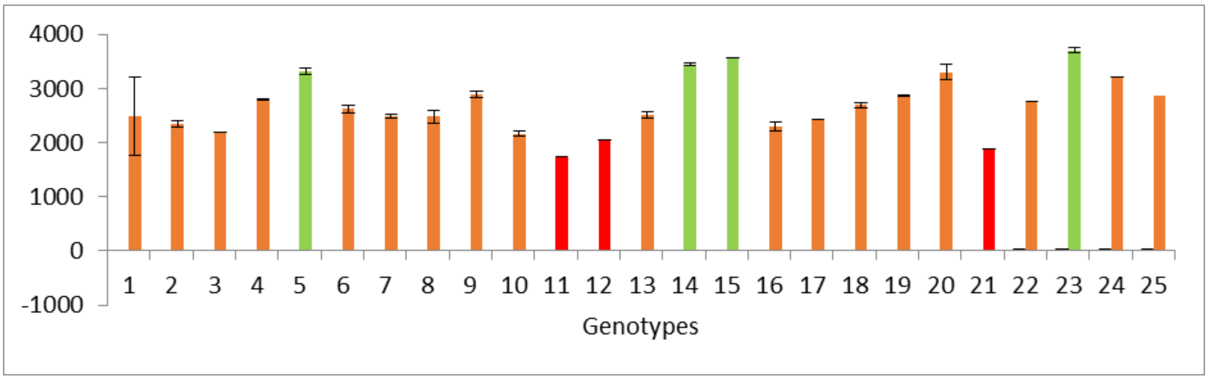

Figure 07. Maximum yield production was recorded in genotypes no. 23,15 ,14&5 while minimum yield production was recorded in genotypes no.12, 21,11. yield 5.60 % is significant. These traits are significant and show variation.

4. Discussion

Plant height is vital role in wheat growth in rainfed areas. Higher plants show better performance under rainfed condition while smaller plants show less performance under rainfed condition. Moderate wheat plants height can be used to develop wheat varieties with improved yield under rainfed condition (Y. Du et al., 2018; S. Schittenhelm 2019).

The plant maturity times follow a predictable trend, with most genotypes falling within a small range. Additionally, planting date and variety selection considerably affected wheat maturity days. Early planting and shorter-duration cultivars shortened maturity times, while later planting and longer-duration kinds extended them. Previous studies have found comparable wheat maturity ranges in rainfed conditions (S. Schittenhelm 2019). This emphasizes the importance of timing and variety choice in rainfed wheat production for timely maturity and results (B. Naseri et al., 2021).

Farmers can use this knowledge to estimate harvesting times and manage crops for best yields. The genotypes' substantial variation in days to heading shows genetic differences. Genetic studies could reveal features or genes that cause early or delayed heading. The low coefficient of variation shows that the data is consistent, making it dependable for agricultural research and decision-making. This study sheds light on the growth patterns of the entry and suggests ways to improve crop management for increased yields (M. Hossain et al., 2018; J. Bányai et al., 2020; F. Ahakpaz et al., 2020).

The germination is high across genotypes despite a significant gap. This may be due to seed quality and germination conditions. These findings shed light on the germination growth variability and performance of different genotypes, which might benefit future studies and crop management techniques (N. Khan et al., 2019; M. Sedri et al., 2019).

It showed that wheat yields varied greatly between trials. Dry regions yielded more than rainy regions in trials. Furthermore, fertilizer and irrigation significantly affected wheat yields (Awan et al., 2020). Fertilizer increased yields in rain-shadow trials compared to wetter trials. Supplemental irrigation increased yields in all regions (Aslam et al., 2003). The results indicate that fertilizer and irrigation can boost wheat yields and boost productivity in rain-fed areas.

The most important finding was that rain-fed wheat varieties yielded more than the control trial. This assists previous research that shows some wheat varieties perform better than others (Malik et al., 2006).

The rain-fed trials additionally revealed that some wheat varieties performed better. Wheat varieties with high water-soluble carbohydrates yielded the best (Singh et al., 2008). Higher levels of water-soluble carbohydrates can boost wheat yield under rainfed condits (Goyal et al., 2011).

5. Conclusion

It is concluded that the performance of 10 rainfed wheat cultivars using yield trial data from three locations in one season. This study found that soil type, sowing timing, and crop season weather were the most important factors affecting cultivar performance. Since this study simply examined rainfed environments, the wheat variety and sowing period should be trusted. Out of 25 wheat genotypes screened, 10 had increased yield potential under rainfed conditions. Wheat producers, seed producers, and governments can employ such strategies to improve wheat productivity, stability, and food security. Further, research can compare these cultivars' performance in different regions and climates. These varieties can be grown in rain-fed areas of Pakistan.

6. REFERENCES

Ahakpaz, F., Hervan, E. M., Roostaei, M., Bihamta, M. R., & Mohammadi, S. (2020). Evaluation of rain-fed wheat (Triticum aestivum L.) genotypes for drought tolerance. Iranian Journal of Genetics and Plant Breeding, 9(1), 28-40.

Anders, S., Cowling, W., Pareek, A., Gupta, K. J., Singla-Pareek, S. L., & Foyer, C. H. (2021). Gaining acceptance of novel plant breeding technologies. Trends in Plant Science, 26(6), 575-587.

Anwaar, H. A., Perveen, R., Mansha, M. Z., Abid, M., Sarwar, Z. M., Aatif, H. M., ... & Khan, K. A. (2020). Assessment of grain yield indices in response to drought stress in wheat (Triticum aestivum L.). Saudi journal of biological sciences, 27(7), 1818-1823.

Asghar, S., Rehman, A. U., Ahmad, N., Ajmal, S., Ahsan, A., Gulnaz, S., ... & Qayyum, A. (2022). Evaluation of Pakistani wheat germplasm for leaf rust resistance at various locations. Plos one, 17(5), e0266695.

Aslam, M., Gill, M. S., Khan, M. H., & Bhatti, M. S. (2003). Performance of different wheat varieties under rainfed conditions. International

Journal of Agriculture and Biology, 5(3), 253-256.
Awan, M. S., Hussain, S., Zafar, Y., Maqbool, M. A., & Ahmad, R. (2020). An assessment of different wheat yield trials under rain-fed conditions. International Journal of Agriculture and Crop Sciences, 13(16), 893-897.
Bányai, J., Kiss, T., Gizaw, S. A., Mayer, M., Spitkó, T., Tóth, V., ... & Vida, G. (2020). Identification of superior spring durum wheat genotypes under irrigated and rain-fed conditions. Cereal research communications, 48(3), 355-364.
Bhardwaj, S. C., Singh, G. P., Gangwar, O. P., Prasad, P., & Kumar, S. (2019). Status of wheat rust research and progress in rust management-Indian context. Agronomy, 9(12), 892.
Blum, A. (1996). Yield potential and drought resistance: are they mutually exclusive. Yield potential in wheat: breaking the barriers, 90-100.
Borlaug, N. E. (1968). Wheat breeding and its impact on world food supply. CIMMYT.
Chaves, M. S., Martinelli, J. A., Wesp-Guterres, C., Graichen, F. A. S., Brammer, S. P., Scagliusi, S. M., & Chaves, A. L. S. (2013). The importance for food security of maintaining rust resistance in wheat. Food security, 5, 157-176.
Chen, W., Wellings, C., Chen, X., Kang, Z., & Liu, T. (2014). Wheat stripe (yellow) rust caused by P uccinia striiformis f. sp. tritici. Molecular plant pathology, 15(5), 433-446.
Du, Y., Chen, L., Wang, Y., Yang, Z., Saeed, I., Daoura, B. G., & Hu, Y. G. (2018). The combination of dwarfing genes Rht4 and Rht8 reduced plant height, improved yield traits of rainfed bread wheat (Triticum aestivum L.). Field Crops Research, 215, 149-155.
Farooq, M., Hussain, M., & Siddique, K. H. (2014). Drought stress in wheat during flowering and grain-filling periods. Critical reviews in plant sciences, 33(4), 331-349.
Farooq, M., Hussain, M., Wahid, A., & Siddique, K. H. M. (2012). Drought stress in plants: an overview. Plant responses to drought stress: From morphological to molecular features, 1-33.
Farooq, M., Wahid, A., Kobayashi, N. S. M. A., Fujita, D. B. S. M. A., & Basra, S. M. A. (2009). Plant drought stress: effects, mechanisms and management. Sustainable agriculture, 153-188.
Giraldo, P., Benavente, E., Manzano-Agugliaro, F., & Gimenez, E. (2019). Worldwide research trends on wheat and barley: A bibliometric comparative analysis. Agronomy, 9(7), 352.
Goyal, A., Kumar, A., & Kumar, U. (2011). Comparative performance of wheat varieties for grain yield under rainfed conditions. International Journal of Plant Breeding
Haroon, U., Khizar, M., Liaquat, F., Ali, M., Akbar, M., Tahir, K., ... & Munis, M. F. H. (2021). Halotolerant plant growth-promoting rhizobacteria induce salinity tolerance in wheat by enhancing the expression of SOS genes. Journal of Plant Growth Regulation, 1-14.
Hossain, M. M., Hossain, A., Alam, M. A., Sabagh, A. E. L., Murad, K. F. I., Haque, M. M., & Das, S. (2018). Evaluation of fifty irrigated spring wheat genotypes grown under late sown heat stress condition in multiple environments of

Bangladesh. Fresen. Environ. Bull, 27(9), 5993-6004.

Iqbal, M. J. (2018). Role of osmolytes and antioxidant enzymes for drought tolerance in wheat. Global wheat production, 51.

Iqbal, M. J. (2018). Role of osmolytes and antioxidant enzymes for drought tolerance in wheat. Global wheat production, 51.

JAFAR, Z. N. (2017) MORPHOLOGICAL AND PHYSIOLOGICAL RESPONSES OF.

Juroszek, P., & von Tiedemann, A. (2013). Climate change and potential future risks through wheat diseases: a review. European Journal of Plant Pathology, 136, 21-33.

Khaeim, H., Kende, Z., Balla, I., Gyuricza, C., Eser, A., & Tarnawa, Á. (2022). The Effect of Temperature and Water Stresses on Seed Germination and Seedling Growth of Wheat (Triticum aestivum L.). Sustainability, 14(7), 3887.

Khakwani, A. A., Dennett, M. D., Munir, M., & Abid, M. (2012). Growth and yield response of wheat varieties to water stress at booting and anthesis stages of development. Pak. J. Bot, 44(3), 879-886.

Khan, M. A., Iqbal, M., Jameel, M., Nazeer, W., Shakir, S., Aslam, M. T., & Iqbal, B. (2011). Potentials of molecular based breeding to enhance drought tolerance in wheat (Triticum aestivum L.). African Journal of Biotechnology, 10(55), 11340-11344.

Khan, N., & Bano, A. (2019). Exopolysaccharide producing rhizobacteria and their impact on growth and drought tolerance of wheat grown under rainfed conditions. PLoS One, 14(9), e0222302.

Leilah, A. A., & Al-Khateeb, S. A. (2005). Statistical analysis of wheat yield under drought conditions. Journal of Arid environments, 61(3), 483-496.

Malik, K. A., & Ali, M. (2006). Performance of wheat varieties under rainfed conditions. Pakistan Journal of Agricultural Sciences, 43(5-6), 250-252.

Maqsood, M., Shehzad, M. A., Ahmad, S., & Mushtaq, S. (2012). Performance of wheat (Triticum aestivum L.) genotypes associated with agronomical traits under water stress conditions. Asian Journal of Pharmaceutical & Biological Research (AJPBR), 2(1).

Masle, J. (1985). Competition among tillers in winter wheat: consequences for growth and development of the crop. Wheat growth and modelling, 33-54.

Mirzaei, A., Naseri, R., & Soleimani, R. (2011). Response of different growth stages of wheat to moisture tension in a semiarid land. World Appl Sci J, 12(1), 83-89.

Monneveux, P., Jing, R., & Misra, S. C. (2012). Phenotyping for drought adaptation in wheat using physiological traits. Frontiers in Physiology, 3, 429.

Naseri, B., & Sabeti, P. (2021). Analysis of the effects of climate, host resistance, maturity and sowing date on wheat stem rust epidemics. Journal of Plant Pathology, 103(1), 197-205.

Odiyo, O. A. (2013). Performance Of Doubled Haploid Maize Inbred Lines In Fl Hybrids Under Stress And Non-stress Conditions (Doctoral dissertation, University of Nairobi).

Pour-Aboughadareh, A., Mohammadi, R., Etminan, A., Shooshtari, L., Maleki-Tabrizi, N., & Poczai, P. (2020). Effects of drought stress on some agronomic and morpho-physiological traits in durum wheat genotypes. Sustainability, 12(14), 5610.

Prasad, P., Savadi, S., Bhardwaj, S. C., & Gupta, P. K. (2020). The progress of leaf rust research in wheat. Fungal biology, 124(6), 537-550.

Razzaq, A., Ammara, R., Jhanzab, H. M., Mahmood, T., Hafeez, A., & Hussain, S. (2016). A novel nanomaterial to enhance growth and yield of wheat. J Nanosci Technol, 2(1), 55-58.

Ren, S., Qin, Q., Ren, H., Sui, J., & Zhang, Y. (2019). Heat and drought stress advanced global wheat harvest timing from 1981–2014. Remote Sensing, 11(8), 971.

Rosell, C. M., Altamirano-Fortoul, R., Don, C., & Dubat, A. (2013). Thermomechanically induced protein aggregation and starch structural changes in wheat flour dough. Cereal Chemistry, 90(2), 89-100.

Schittenhelm, S., Kottmann, L., Kraft, M., Matschiner, K., & Langkamp-Wedde, T. (2019). Agronomic performance of winter wheat grown under highly divergent soil moisture conditions in rainfed and water-managed environments. Journal of agronomy and crop science, 205(3), 283-294.

Sedri, M. H., Amini, A., & Golchin, A. (2019). Evaluation of nitrogen effects on yield and drought tolerance of rainfed wheat using drought stress indices. Journal of Crop Science and Biotechnology, 22, 235-242.

Seleiman, M. F., Al-Suhaibani, N., Ali, N., Akmal, M., Alotaibi, M., Refay, Y., ... & Battaglia, M. L. (2021). Drought stress impacts on plants and different approaches to alleviate its adverse effects. Plants, 10(2), 259.

Shafi, U., Mumtaz, R., Shafaq, Z., Zaidi, S. M. H., Kaifi, M. O., Mahmood, Z., & Zaidi, S. A. R. (2022). Wheat rust disease detection techniques: a technical perspective. Journal of Plant Diseases and Protection, 129(3), 489-504.

Sharma, S. N., Sain, R. S., & Sharma, R. K. (2003). Genetics of spike length in durum wheat. Euphytica, 130, 155-161.

Shen, X., Kong, L., & Ohm, H. (2004). Fusarium head blight resistance in hexaploid wheat (Triticum aestivum)-Lophopyrum genetic lines and tagging of the alien chromatin by PCR markers. Theoretical and Applied Genetics, 108, 808-813.

Sieber, A. N., Würschum, T., & Longin, C. F. H. (2014). Evaluation of a semi-controlled test as a selection tool for frost tolerance in durum wheat (T riticum durum). Plant Breeding, 133(4), 465-469.

Singh, S., & Verma, V. (2008). Performance of wheat genotypes under rainfed conditions. Indian Journal of Plant Physiology, 13(2), 226-231.

Wassmann, R., Jagadish, S. V. K., Heuer, S., Ismail, A., Redona, E., Serraj, R., & Sumfleth, K. (2009). Climate change affecting rice production: the physiological and agronomic basis for possible adaptation strategies. Advances in agronomy, 101, 59-122.