Journal of Physical, Biomedical and Biological Sciences
eISSN: 3005-6489
www.jpbab.com
*J. Phys. Biomed. Biol. Sci., Volume, **2**: 9*

Original Research Artilce **Open Access**

EVALUATION OF WHEAT LINES FOR YIELD AND ITS COMPONENTS UNDER DIFFERENT ECOLOGICAL ZONES

HUSSAIN N[1], ABBAS A[2*], HAMMAD M[1], REHMAN AU[2], ALI T[3], ASHRAF S[4], JAVED MA[2]

[1]PMAS arid Agriculture University, Plant Breeding and Genetics Agriculture Department, Shamsabad, Murree, Road, Punjab Rawalpindi, 46000 Pakistan
[2]Department of Plant Breeding and Genetics, Faculty of Agricultural Sciences, University of the Punjab, P.O BOX. 54590, Lahore, Pakistan
[3]Department of Plant Breeding and Genetics University of Agriculture, Faisalabad, Pakistan
[4]Barani Agricultural Research Institute 13-KM. Talagang Road, P.O. Box-35, Chakwal-48800, Pakistan
**Correspondence author email address: ali.bukhari91112@gmail.com*

(Received, 15th October 2022, Revised 16th June 2023, Published 20th June 2023)

Abstract *Wheat (Triticum aestivum L.) is a staple food in many world countries, including Pakistan. There is a need to provide all inputs necessary for sustainable wheat production. Agriculture has become Pakistan's backbone in GDP and foreign exchange. Data obtained for all the traits were subjected to analysis of variance (ANOVA) to check the genetic variability for all the traits. Highly significant differences were present among all the genotypes for all the traits under study, and results are shown graphically in the results and discussion. As three different trials were assigned to me, their results show that in NUWYT BARI wheat trial, maximum grain yield (4532.3 g/plot) was obtained from line number 1 and with minimum grain yield (2209.3 g/plot) from line number 10. The NUWYT Attock wheat trial shows that maximum grain yield is obtained from line 20 (1778.3 g/plot) and minimum grain yield from line 5 (1398.3 g/plot). Also in NUWYT Piplan, the maximum yield is from line number 16 (933.33 g/plot), and the minimum grain yield is from line 22 (333.33 g/plot). We compile these results with LSD at 0.05 significance, and all data shows that highly significant differences are present among lines for all the traits under all different zones. Yield depends on various variables like stress conditions, early or late sowing, and early or late maturity.*

Keywords: *Environmental factor, Triticum aestivum, Sustainability, grain yield, genotypes*

Introduction

Wheat (*Triticum aestivum*.L.) belongs to the family Poaceae, is hexaploid (2n=6x=42), and self-pollinated in nature. It is used to produce chapatti, cakes, bread, and noodles. It provides a larger amount of nutrients than any other single crop. It is the principal food of many countries, including Pakistan, and provides a very high quantity of protein and energy. It provides food for humans, animal feed, and many other by-products. It is a perfect diet and cheap energy foundation, weighing 5 to 9mm long kernels and weighing 30-55mg. Wheat grain is highly nutritious and world's most extensively adapted crop than any other cereal grain, providing a portion of food to the 1/3rd population of the globe. It contributes about 20% of the world's calories, 70% carbohydrate, 12% protein, 22% crude fibre, 2% fats, 12% water, and 1.8% minerals (Noorka et al., 2013). It was cultivated about 10000 years ago in Fertile Crescent in the Middle East and possibly originated there (Rashid et al., 2012). Wheat accounts for 8.7 percent of value addition in agriculture and 1.7 percent of GDP. Wheat crop production increased by 2.3 percent to 24.946 million tonnes over last year's production of 24.349 million tonnes. Over last year's area under cultivation increased by 1.7 percent to 8,825 thousand hectares (8,678 thousand hectares). The production increased due to increased cultivated area, healthy grain formation, and better yield crop. In Punjab, during 2019-20, wheat production 18377 million tons over the production of 19402 million tons. It is grown in different cropping systems such as wheat-rice, wheat-cotton, wheat-maize, wheat-sugarcane, etc. Now, due to the availability of new high-yielding, semi-dwarf varieties, the yield potential of wheat in our country has increased up to 6-8 tons/ha, but the average production of wheat is still 2.5-3 tons/ha, which is much lower from many other countries of the world. Wheat is usually adapted in temperate regions where annual rainfall ranges from about 500-1250 mm. Due to high rain results in lodging, and diseases such as rusts occur. It also disturbs the field operations such as planting and harvesting. In rainfed areas, it is sown in mid-October. Late wheat sowing in irrigation areas is up to 15th of December. The best sowing time of wheat is 15 to 30th November; after each day, late sowing causes about 15-20kg reduction in yield per day.

The world's population is expected to double in the next century, triggering a big challenge for food security (Iqbal et al., 2003). To meet the global demand of grains, sustainable wheat production is required. But, the average yield is very low because of various biotic factors such as fungi, bacteria, and viruses and abiotic factors such as drought, heat stress, and salinity. It is also due to the poor management of soils, weeds, insect pests, and diseases (Peng et al., 2011). Drought is the most disastrous stress among the other abiotic stresses due to low rainfall and high temperatures. Four critical stages, viz. crown root initiation, booting, anthesis, and grain filling, come during wheat's growth period when water is necessary. The water shortage, particularly during heading and after anthesis, causes a severe reduction in yield. Moreover, wheat is cultivated on rain fed areas and 37% of the developing nations are in semiarid region where water availability during the whole growth period is most challenging due to the climatic change (Dhanda et al., 2004). Soon, the water shortage will be more acute. Pakistan will be the most affected area by this stress because 14 % of the wheat in Pakistan is cultivated as rainfed. The remaining area, under a canal irrigation system, also faces a water shortage because of the canal's closing for equal distribution of canal water between the users (Abbas et al., 2016; Aaliya et al., 2016; Mazhar et al., 2021; Asif et al., 2020).

Drought usually reduces the potential yield of cereals where wheat is cultivated. Due to the less or non-availability of water, development, and plant growth are effected. Water plays an essential role in food security, which will be a most challenging issue in future. Genotypes selection based on good adaptation under water-limited conditions should enhance the wheat productivity of arid zones (Rajaram, 2001). Genetic development of crops for drought tolerance needs a study of the probable mechanisms of drought resistance and a search for the genetic differences between the crops. Four basic approaches were considered for crop development in a limited environment (Turner, 1986). The 1st approach was breeding for higher yield and accepting that this will give yield advantage under stress conditions. The 2nd approach was the breeding for maximum yield under water stress environment. The 3rd approach was selecting cultivars in water-limited environments and then putting the morphological and physiological mechanisms of drought tolerance through traditional breeding (Foulkes et al. 2001). However, the efforts are directed towards selecting genotypes with higher yield potential or selecting the characters accountable for drought resistance. Now, there is a requirement to recognize the new genotypes from available germplasm, which can be essential in increasing wheat production (Ahmed et al., 2013). To combat the above situation, it is now obligatory to advance the varieties of wheat that can tolerate the water shortage without affecting the grain quality (Jatoi et al., 2014). Combining ability analysis helps to find the variability in the gene pool. Significant differences for yield-associated features have been observed for GCA and SCA variances. GCA effect was highly effective for traits like grains/spike, and the SCA effect was significant for yield-linked traits. (Ahmadi et al., 2003). Line × tester is an advantageous technique for finding the GCA and SCA effects that can be used effectively to develop new genotypes. Different lines (female parent) and testers (male parent) are crossed so that each tester crosses every line. This results in the combining ability of different traits, which helps in finding good general and specific combiners that can be used to develop the genotypes that can perform best and give more yield without affecting the quality of grains under stress conditions (Nour et al., 2011). This study aimed to understand and identify the genotypes with a high combining ability for yield related traits based on rain-fed area. This study will help choose good general and specific combiners for future breeding programs (Ali et al., 2013; Ali et al., 2014abc; Ali et al., 2015; Ahsan et al., 2013).

Screening of 25 different wheat genotypes was done based on different traits such as yield/plant, total dry matter, photosynthetic efficiency, and thousand `grain weight under normal and dampness stress situations. Due to stress, plant growth and other yield-related traits decreased, but chlorophyll contents increased. Blue silver genotype exhibited a higher growth rate and yield-associated traits (Akram et al., 2010). Seven different wheat genotypes were evaluated for the efficacy of the additive-dominant model. Among seven genotypes, about five genotypes were local Pakistani varieties, and two were from CIMMYT. Results of the experiment displayed that yield-associated traits had significant differences (Farooq et al., 2010). Gene action and CA effects of yield-related traits were studied using spring and winter wheat. Three spring wheat genotypes were crossed with 10 winter wheat genotypes in L×T plan and were sown in RCBD under three replications. Testers showed significant differences for many traits, such as spike length and days to maturity. Overall, the experimental results showed that two varieties Raj 3765 and PBW 343, could be used for further breeding programs to improve yield (Kapoor et al., 2011). Six different varieties were evaluated under 3 different water managements i.e. 25 percent field capacity (FC), 35 percent FC and 100 percent FC. Among the genotypes, Hashim-8 was best because the relative water contents, harvest index, and biological yield were higher under water stress. This experiment explains the identification of the genotypes that can perform best under water shortage situations (Khakwani et al., 2011). The association between yield and yield-associated traits was studied.

Results disclosed that a positive association was present between yield and traits, including spike length, and it was negatively interrelated with tillers/plant. Thousand-grain weight revealed positive association with yield was a proper criterion of an assortment of promising genotypes (Ali et al., 2016; Ali et al., 2017; Ahmad et al., 2021; Iftikhar et al., 2012). 10 parents were crossed in L×T design to govern the CA of different yield-associated traits. 6 lines and 4 testers used in crosses. GCA/SCA ratio of mean square showed that gene action was non-additive. Two testers disclosed the highest value of CA, while lines, WH-542 and HD-2687 showed the highest value of CA. WH- 542 × Raj-3077 showed the maximum value of hetrobeltosis. This experiment's results confirmed a close relationship between heterobeltosis and SCA (Jain and Sastry, 2012).

Different genotypes of wheat were compared for yield-contributing traits, and results showed a significant difference among genotypes under studied. Some characters, such as hundred-grain weight, yield, and length spike were highly heritable and can be used effectively to select the best genotypes performing better under water-limited conditions. All the genotypes varied in their degree of relationship (Karim and Jahan, 2013). A research was conducted to check the physiological responses and index of drought resistance of different wheat genotypes by applying different soil moisture levels. Relative water contents 100-grain weight were decreased with reduced soil moisture. Chakwal-50 and Bhakkar-2002 were proved best under limited conditions of water based on physiological responses and drought resistance index (Razzaq et al., 2013). The effects of CA on different genotypes were detected using L×T analysis, which provides information about the gene action and genetic mechanism that control certain traits. Three elite wheat lines were crossed with three promising varieties used as testers to develop 9 F1 hybrid combinations. Among parents, female line 9452 and male parents, tester SH-2002 was demonstrated as the top general combiner for yield-related attributes. Crosses 9452×Sehar-2006 and 9452×Lasani- 2008 proved the best combinations for yield improvement. Study additive and non- additive gene action was observed based on this combing ability. These crosses can be used for hybrid breeding or pure line selection after attaining the required homozygosity (Aslam et al., 2014).

Six different high-yielding genotypes were crossed with three testers in L×T manner to make 18 cross combinations planted in RCBD under drought. Significant differences were detected for various traits among lines, testers, and crosses under water stress conditions. Data was analyzed statistically, and results showed that female parent 9452 performed best for various traits under deficiency situations based on its mean performance. Among testers, Chakwal-50 performed best for various traits, and after that Aas-11. The hybrid combination 9272×Aas-11 retained the highest mean value for most traits. According to GCA effects, the female line 9277 and tester Aas-11 were the best general combiners. Based on SCA effects, 9277×Chakwal-50, and 9452×Kohistan-97 were proved best. These hybrid combinations can be used to develop promising cultivars for drought stress (Sharmin et al., 2015). Seven lines (female parents), three testers (male parents), and 21 crosses were tested for GCA and SCA under a water-limiting and normal environment. Additive gene action is present along with non-additive type for yield-related attributes under both environments. DL 803-3 parent line showed good GCA for grain yield under usual and water stress environments. GW190 and GW173 showed significant values of GCA under a water-stress environment for grain yield. GW 322 × GW 173 showed the considerable value of SCA having one good parent for grain yield, which can be exploited by simple recurrent selection for future breeding program. This type of selection additive and non-additive gene action can be fixed for yield-related attributes (Jatav et al., 2017).

Materials and methods

Study area

In this study, three different national wheat yield trials were carried out under rain fed conditions to check their productivity and selection of the best-performing lines from these trials. The experiments were planted with randomized complete block design in the field. The field experiment was conducted at Wheat field area of Barani Agricultural Research Institute (BARI) Chakwal Pakistan. It is situated at 32.9 °N latitude and 72.8 °E longitudes at an altitude of 498m. It has a semi-arid and sub-tropical climate characterized by extremely hot summer and cool winter. The soil is sandy loam in texture with slight salinity. The climate is a subtropical region with dry weather and an average annual rainfall 250-500 mm, mostly during monsoon. The average yearly temperature is 27 °C. The trials named National Uniform Wheat Yield Trial BARI (NUWYT BARI), National Uniform Wheat Yield Trial Attock (NUWYT Attock), and National Uniform Wheat Yield Trial Piplan (NUWYT Piplan) were from the National trials for the selection of lines in development of the variety. All of the three trials were sown on 1st November 2020.

The trials were managed throughout the season different data were collected from these trials to evaluate the best-performing lines. Data that have been taken from the field are given below:

Recorded Observations

The following observation is recorded while evaluating different varieties of wheat:

- Days to heading
- Days to maturity
- Number of tillers
- Number of spikelet per spike
- Plant height (cm)
- Germination percentage
- Yield g/plot

Disease (Rust) data collection

Yellow Rust is the major disease affecting the wheat crop. In this disease, the yellow stripes and spores are visible on the leaves of the wheat plant. It attacks the leaves and affects photosynthesis, affecting the plant's yield. Stripe (yellow) Rust is caused by the basidiomycete fungus *Puccinia striformis*, and is mostly favorable in cool regions with low temperature. Fungus produces bright yellow to orange urediniospores 20 to 30 µm in diameter. These spores are thick and contain pustules on the plant. Urenidiospore production is followed by teliospore production late in the season. No alternate host is understood. The pathogen survives in wheat as dormant mycelium in cooler climates. In the trials, Morocco lines were used as the spreader for the rust disease. The lines were planted after every 10 entries of the trials. These lines have the most rust and can be called spreader lines that help spread 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 attack of Rust.

- Susceptible (S)
- Resistant (R)
- Moderately Resistant (MR)
- Moderately Susceptible (MS)
- Moderately Resistant Moderately Susceptible (MRMS)

E.g. we are studying the rust attack on a line, we will examine the total area of leaf under the rust attack and the response of plant 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 plant is showing moderate resistance.

Management practices of the trials

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

Rouging

The rouging in the wheat yield trials is very important. The off-type or mixture plants in an entry are removed from plots in rouging. This must be done to avoid the seed mixture at the harvesting stage. The plants with different heights that are not uniform are removed from the plots by pulling them along with the roots. The spike of these mixture plants are also different upon observing them closely.

Tagging the Lines

The entries of the trials in the field have to be tagged so that they do not mix up with each other when harvesting. For this purpose, tags were attached along with each entry plot, and the tag contained all the information of that entry, including its entry number, trial name, and the year of the experiment.

Rechecking of Selected Lines

The selected lines, while giving the agronomic score had to be rechecked. The rechecking is done to ensure that the score given to the entries is also under the performance of that entry in the trial.

Counting Tillers/m^2

The wheat tillers in a meter square were counted to check the plant density and the no. of tillers emerging from the single seed. The counting of tillers help in analyzing that which line has the most number of tillers and has high plant density than the others. An "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.

Spikelet/Spike and Spike Length

The number of spikelet in spike vary according to different wheat varieties. When counted from one side in a spike, the spike should be 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. This helps us to analyze the height of spike from the total height of the wheat plant later on when the plant height is measured.

Harvesting

The wheat yield trials must be harvested cautiously to avoid mixing in the seed. The entry plots are harvested manually first with the help of sickle. After harvesting, the bundles of wheat are made separately according to the plots, and the tags are applied to the harvested wheat bundles accordingly. The bundles are threshed in the thresher separately, and the threshing machine is left to run 2-3 minutes after the previous bundle threshing. This helps in cleaning the thresher from the previous entry seed. In this way, mixing of the seed from different entries is avoided.

Bagging

After the harvesting for the storing of the seed, we collect the seed in bags separately to avoid mixing it. Also labelled these bags with the information of the trial of which seed is being packed. Some trials have beds of this seed packed in polythene bags, and some trials have one row of sowing packed in a paper bag.

Storing

The seed is collected separately for each plot in a bag, and tag is also added to the bag containing the entry plot information, the experiment year, and the trial name. These seed bags are shifted to the vehicle and stored in the storeroom.

Statistical analysis

Recorded data are analyzed in the software statistix8.1. Means with. Similar letters are not significantly different, but data are significantly different when letters differ at 0.05 significance level using LSD.

Results and discussion

NUWYT BARI 2020-21

Grain Yield

Grain yield of the wheat crop results from the combined effect of various yield-contributing components (Figure 1). It is evident from the data that early and late maturity significantly affected the grain yield. Significantly, maximum grain yield (4532.3 g/plot) was obtained when the crop was mature early (147 days) and with minimum grain yield (2209.3 g/plot) in case of late sowing and late maturity i.e., 155 days from sowing to maturity. The grain yield was significantly affected by various varieties. However the interaction between sowing time and varieties was insignificant (Tahir et al., 2009).

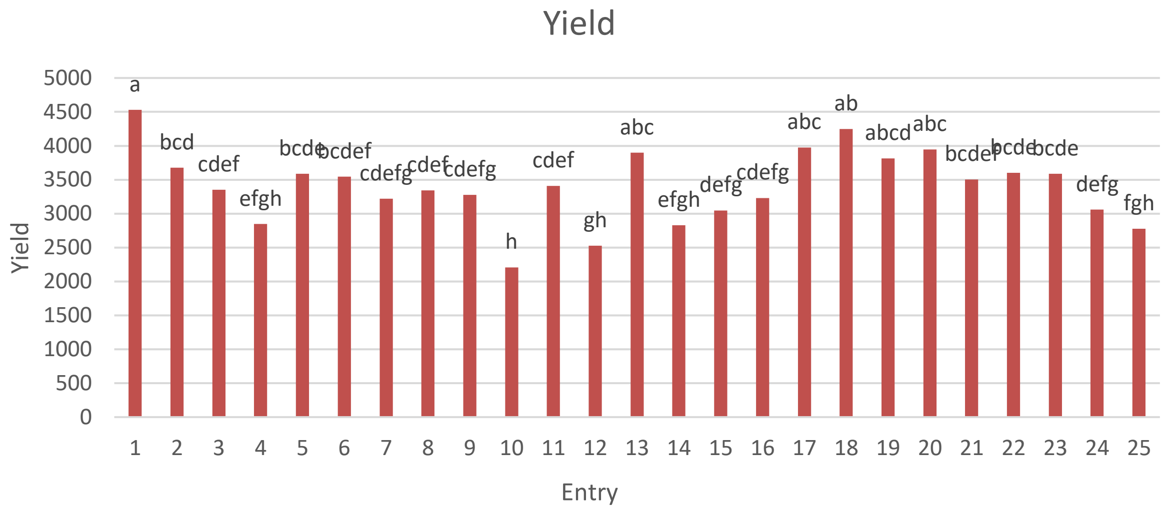

Figure 1: Shows the significant difference of yield among the lines of NUWYT BARI 2020-21

Days to Heading

Statistical data analysis showed significant differences for days to heading among wheat lines as shown in Figure 2. According to the analysis of variance, maximum days to heading were recorded in line 15 (122 days) and followed by 12 and 19 lines. And the minimum number was recorded in line 16 (115 days). The comparison of lines showed that the performance of line 16 was better than all other lines. It takes minimum time to reach the heading. The differences in days to heading among different wheat lines might be due to their genetic makeup (Raza et al., 2017).

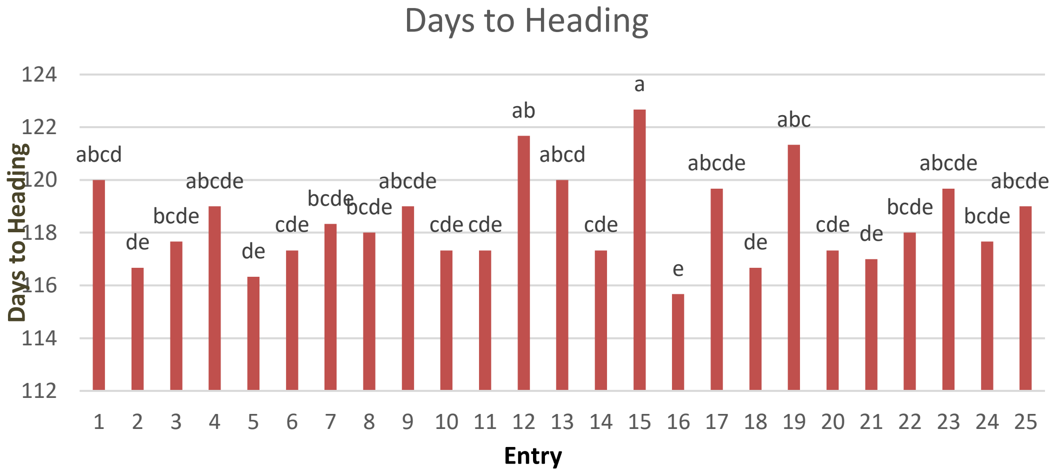

Figure 2: Shows the significant difference of days to heading among the lines of NUWYT BARI 2020-21

Days to Maturity

Analysis of variance showed highly significant ($P<0.01$) differences among wheat genotypes for days to maturity, as shown in Figure 3. Mean data showed that days to maturity ranged from 147 to 156. Line 21 took a minimum days to maturity, while 13 took a maximum days to maturity. Days to maturity were positive and significantly correlated with spike density while non-significant with other parameters like plant height and germination percentage. This corresponds to the study (Ullah et al., 2014), which reported a significant positive correlation between days to maturity, days to heading, biological yield, and grain yield.

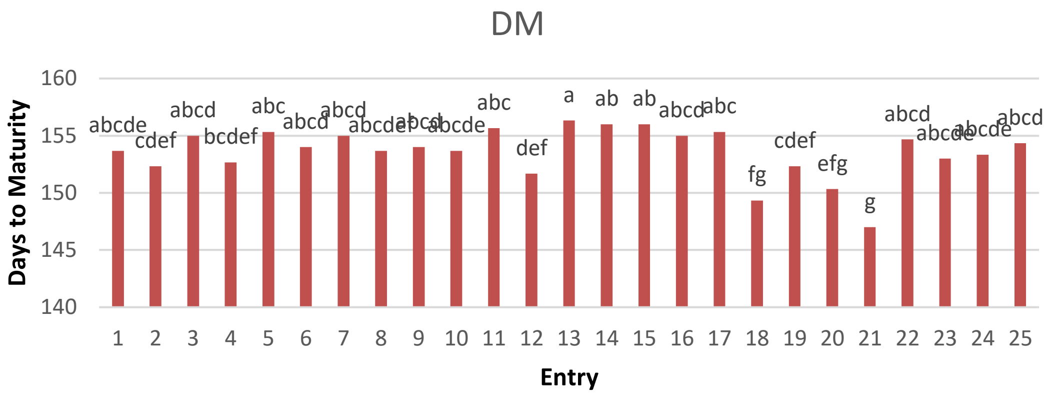

Figure 3: Shows the significant difference in days to maturity among the lines of NUWYT BARI 2020-21

Plant Height

The analysis of variance showed that the effect of the year 2020-21 variety interaction on plant height was significant, as shown in Graph 4. The line 9 attained the maximum height (120 cm) in year 2020-21, whereas line 21 had the least plant height (105cm) during 2020-21 as shown in Figure 4. The main effect of variety on plant height was highly significant, while the main effect of year on plant height was non-significant. It observed that the wheat varieties significantly affected plant height, while the environment did not. It suggests that suitable varieties adapted well in these conditions can be selected (Kabir et al., 2017).

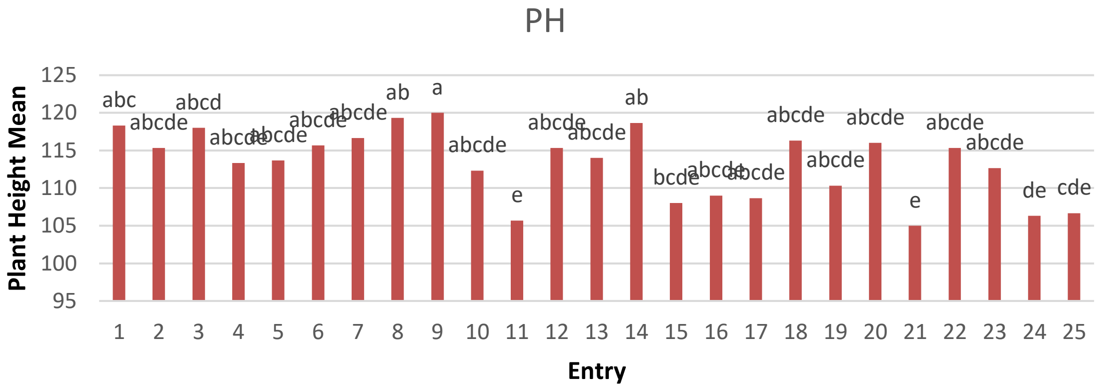

Figure 4: Shows the significant difference in plant height among the lines of NUWYT BARI 2020-21

Germination Percentage

According to the analysis of covariance Figure 5, lines 10, 12, 16, and 18 show the maximum germination percentage, and line 25 shows the least germination. The results of (seedling growth) present study show that growth attributes were significantly affected by increasing the physiological and biochemical attributes concentration (Yadav et al., 2018). Concentration above 4.5 mg/kg of soil is toxic to plant health, decreasing germination % (Kanwal et al., 2020).

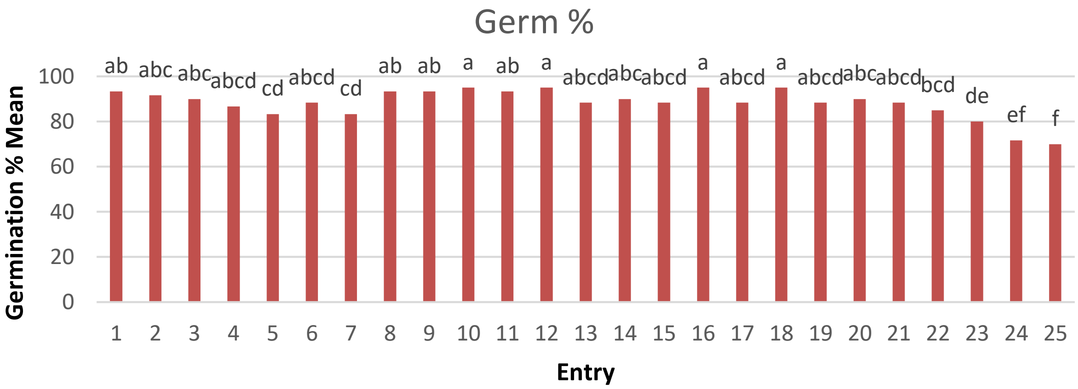

Figure 5: Shows the significant difference of germination percentage among the lines of NUWYT BARI 2020-21

NUWYT PIPLAN 2020-21

Yield

Grain yield of the wheat crop results from the combined effect of various yield-contributing components (Figure 6). It is evident from the data that early and late maturity affected significantly the grain yield. Significantly maximum grain yield (933.33 g/plot) was obtained when crop matured early and with minimum grain yield (333.33 g/plot) in case of late sowing and late maturity. The grain yield was significantly affected by various varieties. However the interaction between sowing time and varieties was found to be non-significant (Tahir *et al*., 2009).

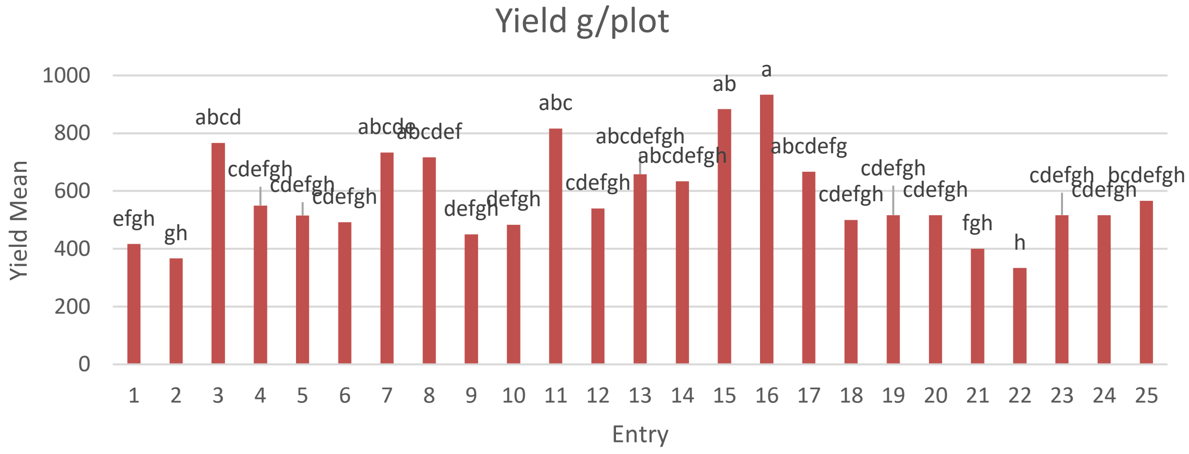

Figure 6: Shows the significant difference of yield among the lines of NUWYT Piplan 2020-21

NYWYT Attock 2020-21

Yield

Grain yield of the wheat crop results from the combined effect of various yield-contributing components (Figure 7). It is evident from the data that early and late maturity affected significantly the grain yield. Significantly, maximum grain yield (1778.3 g/plot) was obtained when crop matured early and with minimum grain yield (1398.3 g/plot) in case of late sowing and late maturity. The grain yield was significantly affected by various varieties. However the interaction between sowing time and varieties was insignificant (Tahir et al., 2009).

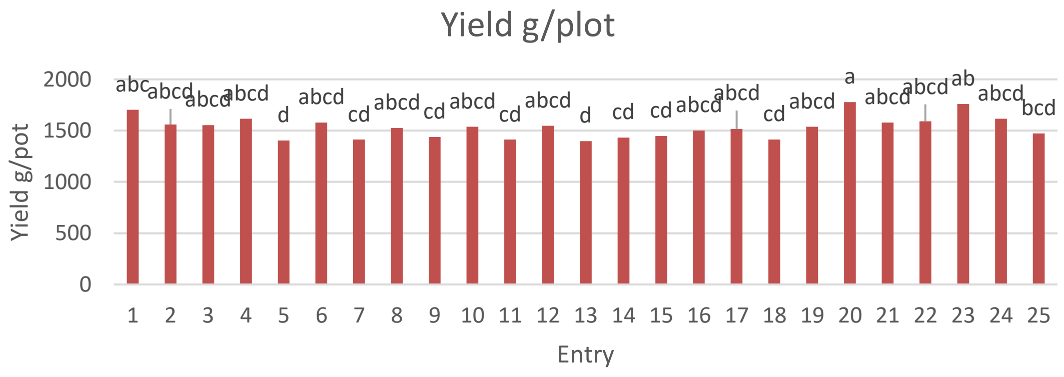

Figure 7: Shows the significant difference of yield among the lines of NUWYT Attock 2020-21

References

Aaliya, K., Qamar, Z., Ahmad, N. I., Ali, Q., Munim, F. A., & Husnain, T. (2016). Transformation, evaluation of gtgene and multivariate genetic analysis for morpho-physiological and yield attributing traits in Zea mays. *Genetika*, *48*(1), 423-433.

Abbas, H. G., Mahmood, A., & Ali, Q. (2016). Zero tillage: a potential technology to improve cotton yield. *Genetika*, *48*(2), 761-776.

Ahsan, M., Farooq, A., Khaliq, I., Ali, Q., Aslam, M., & Kashif, M. (2013). Inheritance of various yield contributing traits in maize (Zea mays L.) at low moisture condition. *African Journal of Agricultural Research*, *8*(4), 413-420.

Ahmad, M., Ali, Q., Hafeez, M., & Malik, A. (2021). Improvement for biotic and abiotic stress tolerance in crop plants. *Biological and Clinical Sciences Research Journal*, *2021*(1).

Ali, Q., Ahsan, M., Ali, F., Aslam, M., Khan, N. H., Munzoor, M., Mustafa, H. S. B., & Muhammad, S. (2013). Heritability, heterosis and heterobeltiosis studies for morphological traits of maize (Zea mays L.) seedlings. *Advancements in Life Sciences*, *1*(1).

Ali, Q., Ahsan, M., Kanwal, N., Ali, F., Ali, A., Ahmed, W., Ishfaq, M., & Saleem, M. (2016). Screening for drought tolerance: comparison of maize hybrids under water deficit condition. *Advancements in Life Sciences*, *3*(2), 51-58.

Asif, S., Ali, Q., & Malik, A. (2020). Evaluation of salt and heavy metal stress for seedling traits in wheat. *Biological and Clinical Sciences Research Journal*, *2020*(1).

Ali, Q., Ali, A., Ahsan, M., Nasir, I. A., Abbas, H. G., & Ashraf, M. A. (2014a). Line× Tester analysis for morpho-physiological traits of Zea mays L seedlings. *Advancements in Life sciences*, *1*(4), 242-253.

Ali, Q., Ali, A., Awan, M. F., Tariq, M., Ali, S., Samiullah, T. R., ... & Hussain, T. (2014b). Combining ability analysis for various physiological, grain yield and quality traits of Zea mays L. *Life Sci J*, *11*(8s), 540-551.

Ali, F., Ahsan, M., Ali, Q., & Kanwal, N. (2017). Phenotypic stability of Zea mays grain yield and its attributing traits under drought stress. *Frontiers in plant science*, *8*, 1397.

Ali, F., Kanwal, N., Ahsan, M., Ali, Q., Bibi, I., & Niazi, N. K. (2015). Multivariate analysis of grain yield and its attributing traits in different maize hybrids grown under heat and drought stress. *Scientifica*, *2015*.

Ali, Q., Ali, A., Waseem, M., Muzaffar, A., Ahmad, S., Ali, S., ... & Tayyab, H. (2014c). Correlation analysis for morpho-physiological traits of maize (Zea mays L.). *Life Science Journal*, *11*(12), 9-13.

Akram, H. M., Sattar, A., Ali, A., & Nadeem, M. A. (2010). Agro-physiological performance of wheat genotypes under moisture stress conditions. *J. Agric. Res*, *48*(3), 361-368.

Afzal, A., Riaz, A., Naz, F., Irshad, G., Shah, M. K., & Ijaz, M. (2018). Significance of recent discoveries in stripe rust management. *Pakistan Journal of Phytopathology*, *30*(2), 207-211.

Abdel-Nour, N. A., & Fateh, H. S. A. (2011). Influence of sowing date and nitrogen fertilization on yield and its components in some bread wheat genotypes. *Egypt. J. Agric. Res*, *89*(4), 1413-1433.

Aslam, R., Munawar, M., & Salam, A. (2014). Genetic architecture of yield components accessed through line× tester analysis in wheat (Triticum aestivum L.). *Universal Journal of Plant Science*, *2*(5), 93-96.

Calderini, D. F., Dreccer, M. F., & Slafer, G. A. (1995). Genetic improvement in wheat yield and associated traits. A re-examination of previous results and the latest trends. *Plant breeding*, *114*(2), 108-112.

Dixit, A., & Nema, S. (2018). Wheat Leaf Disease Detection Using Machine Learning Method-A Review. *International Journal of Computer Science and Mobile Computing*, *7*(5), 124-129.

Fellahi, Z. E. A., Hannachi, A., Bouzerzour, H., & Boutekrabt, A. (2013). Line× tester mating design analysis for grain yield and yield related traits in bread wheat (Triticum aestivum L.). *International Journal of Agronomy*, *2013*.

Farooq, J., Khaliq, I., Khan, A. S., & Pervez, M. A. (2010). Studying the genetic mechanism of some yield contributing traits in wheat (Triticum aestivum). *Int. J. Agric. Biol*, *12*(2), 241-246.

Habib, M., Awan, F. S., Sadia, B., & Zia, M. A. (2020). Genome-Wide Association Mapping for Stripe Rust Resistance in Pakistani Spring Wheat Genotypes. *Plants*, *9*(9), 1056.

Iftikhar, R., Khaliq, I., Ijaz, M., & Rashid, M. A. R. (2012). Association analysis of grain yield and its components in spring wheat (Triticum aestivum L.). *American-Eurasian Journal of Agricultural and Environmental Sciences*, *12*(3), 389-392.

Jain, S. K., & Sastry, E. V. D. (2012). Heterosis and combining ability for grain yield and its contributing traits in bread wheat (Triticum aestivum L.). *Journal of Agriculture and Allied Science*, *1*(1), 17-22.

Kempe, K., Rubtsova, M., & Gils, M. (2014). Split-gene system for hybrid wheat seed production. *Proceedings of the National Academy of Sciences*, *111*(25), 9097-9102.

Karim, M. H., & Jahan, M. A. (2013). Comparative study of yield and yield contributing traits of different genotypes in bread wheat. *Journal of Agricultural and Biological Science*, *8*(2), 147-151.

Kanwal, A., Farhan, M., Sharif, F., Hayyat, M. U., Shahzad, L., & Ghafoor, G. Z. (2020). Effect of industrial wastewater on wheat germination, growth, yield, nutrients and bioaccumulation of lead. *Scientific reports*, *10*(1), 1-9.

Khakwani, A. A., Dennett, M. D., & Munir, M. (2011). Drought tolerance screening of wheat varieties by inducing water stress conditions. *Songklanakarin Journal of Science & Technology*, *33*(2).

Kapoor, E., Mondal, S. K., & Dey, T. (2011). Combining ability analysis for yield and yield contributing traits in winter and spring wheat combinations. *J. Wheat Res*, *3*(1), 52-58.

Kiszonas, A. M., & Morris, C. F. (2018). Wheat breeding for quality: A historical review. *Cereal Chemistry*, *95*(1), 17-34.

Lam, Y., Sze, C. W., Tong, Y., Ng, T. B., Tang, S. C. W., Ho, J. C. M., & Zhang, Y. (2012). Research on the allelopathic potential of wheat.

Mazhar, T., Ali, Q., & Malik, M. S. R. A. (2020). Effects of salt and drought stress on growth traits of Zea mays seedlings. *Life Science Journal*, *17*(7), 48-54.

Qin, X., Zhang, F., Liu, C., Yu, H., Cao, B., Tian, S., & Siddique, K. H. (2015). Wheat yield improvements in China: Past trends and future directions. *Field Crops Research*, *177*, 117-124.

Razzaq, A., Ali, Q., Qayyum, A., Mahmood, I., Ahmad, M., & Rasheed, M. (2013). Physiological responses and drought resistance index of nine wheat (Triticum aestivum L.) cultivars under different moisture conditions. *Pak. J. Bot*, *45*(S1), 151-155.

Sarwar, M. A., Abid, A., Hussain, M., Abuzar, M. K., Ijaz, A., & Latif, S. (2018). A step towards the sustainable wheat production with integrated nutrient management strategies under pothwar conditions. *Pakistan Journal of Agricultural Research*, *31*(1).

Singh, R. P., Singh, P. K., Rutkoski, J., Hodson, D. P., He, X., Jørgensen, L. N., & Huerta-Espino, J. (2016). Disease impact on wheat yield potential and prospects of genetic control. *Annual review of phytopathology*, *54*, 303-322.

Seymour, M., Kirkegaard, J. A., Peoples, M. B., White, P. F., & French, R. J. (2012). Break-crop benefits to wheat in Western Australia–insights from over three decades of research. *Crop and Pasture Science*, *63*(1), 1-16.

Tahir, M., Ali, A., Nadeem, M. A., Hussain, A., & Khalid, F. (2009). Effect of different sowing dates on growth and yield of wheat (Triticum aestivum L.) varieties in district Jhang, Pakistan. *Pak. j. life soc. sci*, *7*(1), 66-69.

Tahir, S., Ahmad, A., Khaliq, T., & Cheema, M. J. M. (2019). Evaluating the impact of seed rate and sowing dates on wheat productivity in semi-arid environment. *Int. J. Agric. Biol*, *22*(1), 57-64.

Ullah, S. F., Hassan, G., Ahmad, N., Javed, S., Ahmad, I., & Ali, R. (2014). Evaluation of Wheat Advance Lines under Rainfed Conditions. *International Journal of Scientific Research in Agricultural Sciences*, *1*(6), 97-101.

Virk, A., Sheikh, K., & Marwat, A. (2003). Northern areas strategy for sustainable development. *IUCN Pakistan*.

Wang, Q., Li, F. R., & Zhang, Z. H. (2008). Effects of different irrigation and nitrogen supply levels on nitrate-N dynamics in a recently reclaimed sandy farmland in Heihe River basin. *Huan jing ke xue= Huanjing kexue*, *29*(7), 2037-2045.

Declaration

Conflict of interest

The researchers affirm that there were no financial or commercial ties that might be seen as a potential conflict of interest throughout the research's execution.

Data Availability statement

All data generated or analyzed during the study have been included in the manuscript.

Ethics approval and consent to participate

These aspects are not applicable in this research.

Consent for publication

Not applicable

Funding

There were no sources providing support, for this research.