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Research Article

Evaluating the Bread Wheat Germplasm for Yield and Adult Plant Resistance to Yellow Rust under Field conditions of Mansehra

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ABSTRACT

Yellow rust (*Puccinia Striiformis* f. sp. tritici) is a major disease that significantly impacts wheat yield and grain quality. Yellow rust poses a serious threat to wheat production in cooler areas of Pakistan. To evaluate the resistance at adult plant stage against yellow rust a set of 47 wheat varieties alongside two checks i-e; Kohat-2000 and Kohat-2017 were planted during 2018–19 cropping season. Data were recorded on days to heading, days to maturity, plant height (cm), flag leaf area (cm2), tillers m-2, spike length (cm), grains spike-1 (no.), 1000-grain weight (g), grain yield (g plot-1) and yellow rust scoring. Significant differences were found between genotypes for days to heading and 1000-grain weight. According to adjusted mean data, Shahkar-2013 had the lowest ideal days to heading (112 days) and days to maturity (157 days), but TD-1's plant height (69 cm) was the highest. Pakistan-2013 had the highest results for flag leaf area (37.3 cm2), tillers m-2 for Frontana (172 m-2), grains spike-1 for Gold-2016 (60 grains), and spike length (12.5 cm), while NIFA-Lalma-2013 had the highest grain weight (70 g) and Pavan had the highest grain yield plot-1 (250 g). Pavan, Frontana, Wadaan-2017, Tatara-96, NIFA Aman, Parula, Fateh Jhang, Pirsabak-2013, Paseena-2017, Khushal-69, Gold-2016, Pirsabak-2005, Ujala, Khaista-2017, Kohat-2017, Pirsabak-2015, and Pakistan-2013 are among 17 genotypes that were found to be high yielding and disease resistant based on yield as well as resistant against yellow rust. These 17 genotypes should be promoted for widespread cultivation in the Mansehra region to enhance wheat productivity and ensure food security while minimizing the impact of yellow rust.

Keywords: Wheat, Yellow Rust, Resistance, Screening, Yield.

INTRODUCTION

Wheat has been the utmost significant cereal crop in Pakistan, getting noteworthy consideration in agricultural platforms and being cultured widely on productive acreage. The countless mainstreams of the global inhabitants in terms of production and nourishment it is a critical cereal crop from all other cereals (Azam & Shafique, 2017). Wheat is amongst the principal cereal crop of the creation, which contributes 36% of solid food to the worldwide populations. It contributes 20% of foods Calories. Its production is rottenly influenced by climatically changes worldwide and swelling the scarcity of water levies and bettering the Eco atmosphere. (Khan *et al.,* 2011). In areas where cool and humid ecological conditions stripe rust often referred to as yellow rust has been a more serious disease.

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Mansehra has historically faced frequent outbreaks of stripe rust with farmers reporting significant yield losses. This recurrent epidemic status can be attributed to the region's susceptibility to disease establishment and spread, particularly through the vast production of airborne urediniospores. These conditions make the region an important area for understanding pathogen dynamics and evaluating resistant wheat germplasm (Chen *et al.,* 2014). From a distance areas with just impacted plants are frequently visible (Horst, 2013). This widespread phenomenon, which results in grain losses of 30% to 100%, is a serious global threat to wheat productivity. Berberis vulgaris was identified as the stripe rust alternative host during prolonged insecurity (Kolmer, 2005). By way of proven adaptability and flexibility to changing climatic conditions wheat rusts can flourish in a variety of locations across the globe. In general, a variety of strategies are being used to combat stripe rust disease. It is clear that agronomic techniques and the application of certain pesticides can successfully lower losses to a certain degree. Host genetic resistance to switch stripe rust is the most environmentally beneficial, economical, and friendly method available (Chen, 2007). In the end, breeding against resistant cultivars is extremely frustrating. In background packages, this resistance is used in a highly noticeable way and is very simple to include in enhanced germplasm. It also provides a high level of crop security (Singh *et al.,* 2000). Mansehra is a unique ecological and agricultural context makes it a natural hotspot for stripe rust and an invaluable site for conducting research. The study will not only contribute to understanding yellow rust resistance but also provide high-performing wheat genotypes for commercialization, ensuring food security and sustainable wheat production in stripe rust-prone areas. However, the current study aims to assess the performance of bread wheat germplasm for yield and yellow rust resistance and to identify high yielding and yellow rust resistant wheat genotypes at strong adult plant resistance level suitable for commercialization in Mansehra.

MATERIALS AND METHODS

A set of 47 wheat genotypes alongside two checks (Kohat-2000 and Kohat-2017) were field tested during the 2018–19 crop season at Agriculture Research Farm, Hazara University Mansehra, Pakistan.

Field layout, sowing, and crop husbandry

On December, 4, 2018, the experimental material was planted in three blocks using an Alpha- lettace design as an observational nursery. Each block has two control entries (which are the same for all three blocks) and fifteen test genotypes. Every entry was fixed in two rows, each measuring one meter in length and thirty centimeters in length. While the bread wheat genotypes were assigned to different blocks, each incomplete block featured a set of control cultivars, and each control variety was often arising in all other blocks.

Agronomic data

Agronomic data for a number of morpho-yield traits such as days to heading, days to maturity, flag leaf area (cm^2), plant height (cm), spike length (cm), tillers m^{-2}, 1000 grain weight (g), grain yield (g plot^{-1}), and yellow rust scoring were also recorded in addition to yellow rust data.

Disease scoring and analysis

In addition to natural infection used for disease scoring, the specified site (Mansehra) is a hotspot against yellow rust disease. This is often done when the crop has reached the heading stage. Following the procedure Leogering (1959) indicated, data on stripe rust response and severity were documented. By a modified cobb scale severity was determined by calculating the percentage of rust impurity on plants (Peterson *et al.,* 1948).

Statistical analysis

The data for every trait was examined using analysis of variance (ANOVA), suitable for augmented field block design as outlined by Federer (1956).

RESULTS

Days to heading

Wheat genotypes with optimum days to heading are well adjusted to particular climatic conditions confirming suitable development and grain filling. Analysis of variance revealed significant differences among genotypes, lines, and checks as well as between checks and lines for days to heading (Table 1). However, Bhutto *et al.* (2016) testified the similar findings regarding days to heading. However, this result contrasts with other studies that found non-significant genetic variation in heading time between wheat genotypes which is vital for adjusting to dissimilar growing conditions (Maccaferri *et al.,* 2016). The adjusted mean data for days to heading are presented in (Figure 1). Earliest heading is considered as desirable trait in wheat. In order to cope with the water shortage plants under stress tend to finish their life cycles as quickly as possible. Because terminal stress stimulates the reproductive stage early the number of days required to initiate spikes in wheat under stress environments is often reduced (Riaz, 2003). Similar early heading trends under stressful conditions were noted in the current study. In a stressful environment, wheat genotypes started heading earlier. The mean number of days to heading was 118 with a range of 112 to 124 days. The number of days required to initiate heads along with other physiological parameters is often used by plant breeders to determine when a wheat crop is fully mature. Midst lines, 15 and 38 out of 45 lines headed earlier than Kohat-2017 (118 days) and Kohat-2000 (123 days), respectively. Early heading is beneficial as it helps crops escape terminal drought and heat stress, which are critical factors affecting yield stability under adverse conditions (Batten *et al.,* 2012; Zhang *et al.,* 2015). Earliest heading was noticed for Shahkar- 2013 (112 days), whereas maximum days to heading were recorded for Saleem-2000 (124 days). Our findings also support those of Kashif and Khaliq (2004) who noted that spring wheat showed a strong response to selection for anthesis.

Table 1. Means squares for different morpho-yield parameters in wheat genotypes during 2018-19.

Traits	Genotypes(df=46)	Lines (df=44)	Checks (df=1)	L vs. C (df=1)	Error (df=4)
Days to heading	9.38^{**}	8.19^{**}	37.50^{**}	33.68^{**}	0.33
Days to maturity	2.06^{NS}	1.71^{NS}	4.17^{NS}	15.30^{**}	0.83
Plant height	70.34^{NS}	69.69^{NS}	168.89^{NS}	5.01^{NS}	0.09
Flag leaf area	99.26^{NS}	100.11^{NS}	125.74^{NS}	3.30^{NS}	0.14
Tillers m^{-2}	487.10^{NS}	487.07^{NS}	812.98^{NS}	206.77^{NS}	167.43
Grains $spike^{-1}$	65.57^{NS}	67.74^{NS}	4.84^{NS}	30.64^{NS}	20.61
Spike length	1.23	1.02	6.97	4.99	0.37
1000-grain weight	37.35**	32.18**	210.04**	92.06**	1.41s
Grain yield $plot^{-1}$	252.91^{NS}	261.48^{NS}	9.38^{NS}	119.45^{NS}	125.00

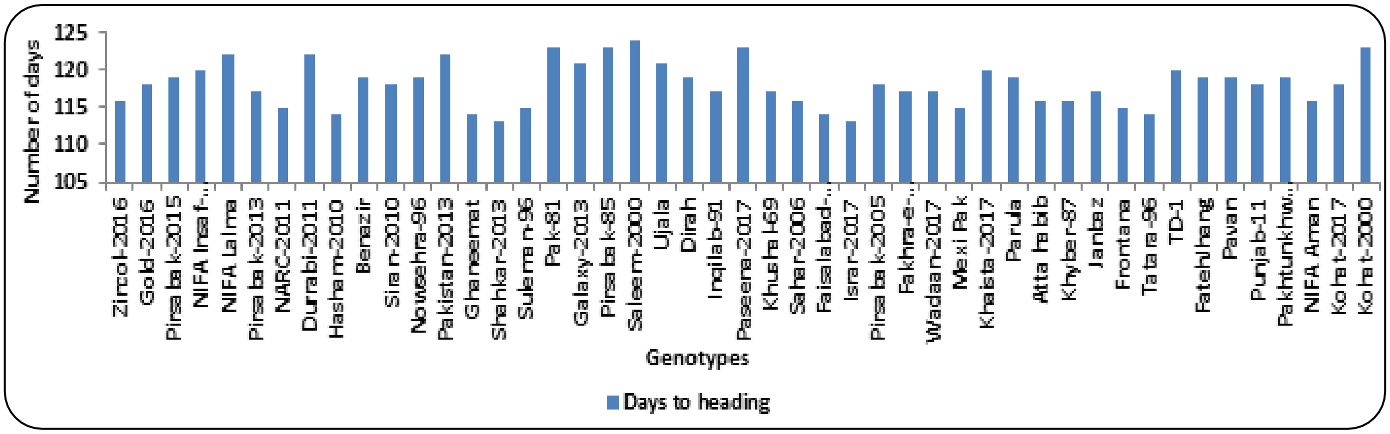

Figure 1. Bar- graph representing the mean for days to heading of 47 wheat genotypes at Mansehra during 2018-19 cropping season.

Days to maturity

In a wheat-based cropping pattern, days to maturity are crucial because they establish whether a crop is appropriate for a certain location within the current cropping system. Wheat cultivars are divided into three categories based on duration: early, medium, and late. Due to their nutrient efficiency and fertilizer responsiveness, early maturing wheat cultivars are preferred (Golabadi *et al.,* 2005). As a result, early maturing is the breeder's top priority when it comes to emergency sowing; hence, fewer days to maturity are desired, and wheat breeders are eager to create early maturity wheat cultivars. Analysis of variance revealed non-significant differences among genotypes, lines, checks, and checks vs. lines for days to maturity (Table 1). Non-significant differences amid the genotypes for days to maturity were also renowned by Ali *et al.* (2007). Significant differences across bread wheat genotypes for days to maturity were demonstrated by Anwar et al. (2009). The adjusted mean data for days to maturity is given in (Figure 2). The earliest maturity is assumed as a good character in wheat crop. The mean number for days to maturity was (161days), with a range of (157 days) to (164 days). In wheat husbandry shorter days to physiological maturity are ideal as early-maturing cultivars can escape both inherent and extrinsic challenges can free up the soil for successive crops and allow agricultural crops to reach the market more quickly thus, make the most of incomes

(Faisal *et al.,* 2005). Out of 45 lines, lines 23 and 16 matured before Kohat-2017 (161 days) and Kohat-2000 (162 days). Shahkar-2013 had the earliest maturity (157 days), whereas Suleman-96 had the longest days to heading (164 days). The results of Akram *et al.* (2008) also showed that farmers and end consumers prefer wheat genotypes with the fewest days to physiological maturity.

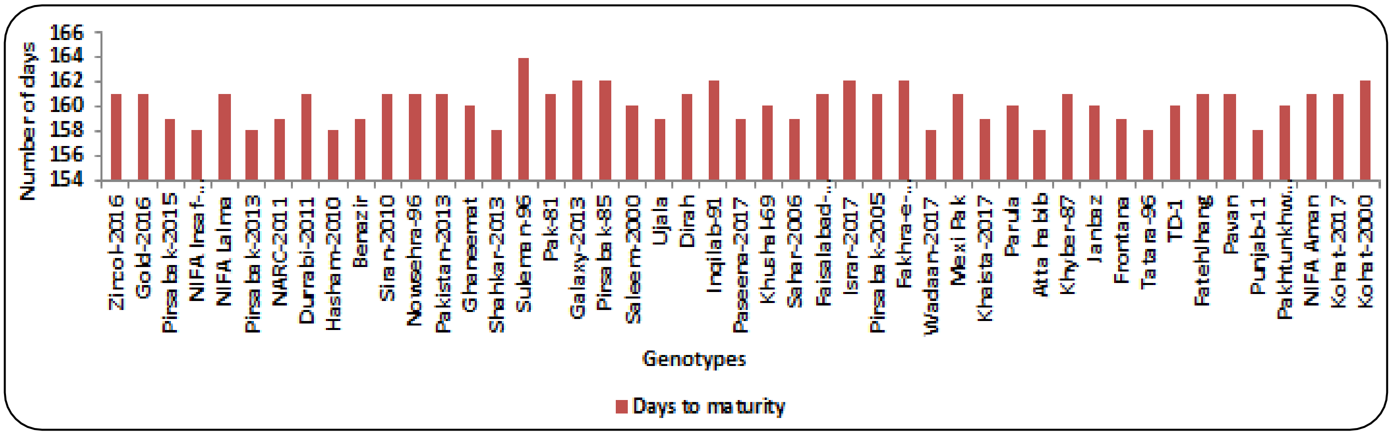

Figure 2. Bar- graph representing the mean for days to maturity of 47 wheat genotypes at Mansehra during 2018-19 cropping season.

Plant height

Grain yield is positively impacted by medium plant height; wheat breeders are quite worried about plant stature. Analysis of variance exhibited non-significant differences among genotypes, lines, checks, and checks vs. lines for plant height (Table 1). Additionally, Khan (2013) found that genotypes did not significantly differ in plant height. On the other hand Majeed *et al.* (2011) and Akbar *et al.* (2009) previously demonstrated highly significant genetic variation for plant height in wheat under stress conditions and came to the conclusion that genetic variety might be effectively improved in wheat by making novel crosses through hybridization. Adjusted mean data for plant height is shown in (Figure 3). Wheat varieties that are semi-dwarf are seen as favorable. According to Bakhsh *et al.* (2003) little-heighted genotypes are extremely chemically sensitive. Along with other factors plant height is one of the key factors that affect yield. One important factor in wheat breeding programs is plant stature. The green revolution was brought about by the small stature of wheat plants. Plant breeders choose tall options for areas with a natural drought and short height genotypes for areas where lodging is likely to occur (Khan *et al.* 2010). Moreover, it was renowned that these treatments were relatively challenging to accommodate. The average height of the plants was 91 cm, with a range of 69 to 113 cm. Thirteen and fourteen of the forty-five lines yielded plants that were shorter than Kohat-2017 (161 days) and Kohat-2000 (162 days), respectively. Minimum plant height was noticed for TD-1 (69 cm), whereas maximum value for plant height was recorded for NIFA Insaf- 2015 (113 cm).

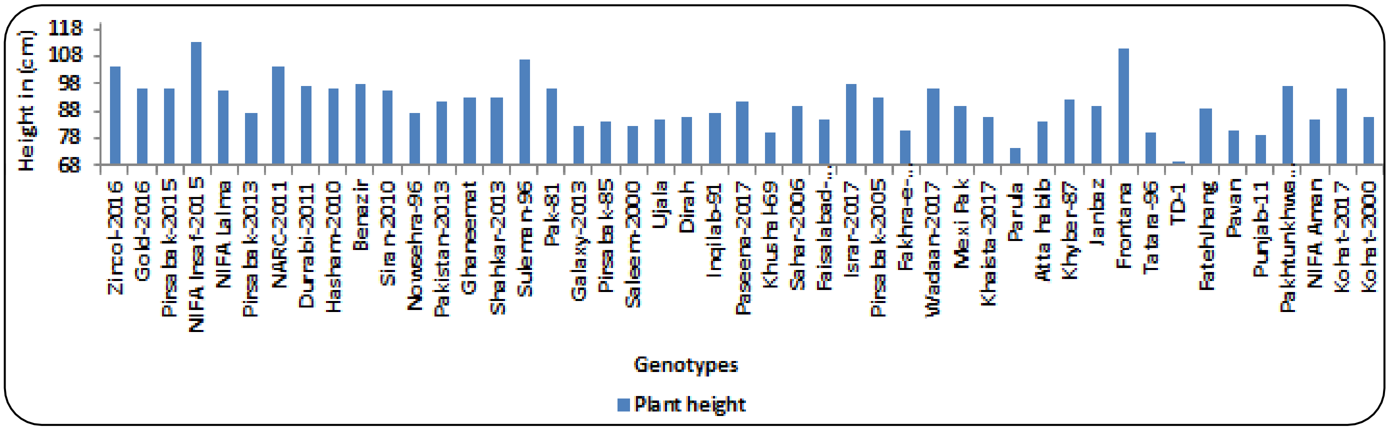

Figure 3. Bar- graph representing the mean for plant height of 47 wheat genotypes at Mansehra during 2018-19 cropping season.

Flag leaf area

The flag leaf area plays an important role in supporting photosynthesis which subsidizes to improved grain yield.

Larger leaf areas are mainly valuable as they are crucial for efficient light capture as reported by Riaz (2003). Analysis of variance for flag leaf area exhibited non-significant differences between genotypes, lines, checks, and the comparison of checks versus lines (Table 1). However, Iqbal *et al.* (2017) testified significant variations in flag leaf area between wheat genotypes. Genotypes with larger flag leaf areas reveal a greater ability for fixing inorganic carbon through photosynthesis. This typical character supports grain filling during the post-anthesis stage by expediting glucose transport to the grains (Akram *et al.,* 2008). Flag leaf area is a dynamic morphological trait for photosynthetic activity directly influencing grain yield. In wheat larger flag leaf area is ideal due to its significant contribution to final grain yield through improved photosynthesis. Adjusted mean data for flag leaf area is presented in (Figure 4) with values ranging from (15.4 cm^2) to (37.3 cm^2) and a mean of (26.3 cm^2). Among the 45 lines tested, 24 and 13 lines exceeded the flag leaf area of the check cultivars Kohat-2000 (24.9 cm^2) and Kohat-2017 (30.1 cm^2), respectively. The smallest flag leaf area was witnessed in Punjab-11 (15.4 cm^2) while the largest was noted in Pakistan-2013 (37.3 cm^2). In different wheat populations the flag leaf area has been exposed to have a significant positive correlation with grain yield (Salman *et al.,* 2014).

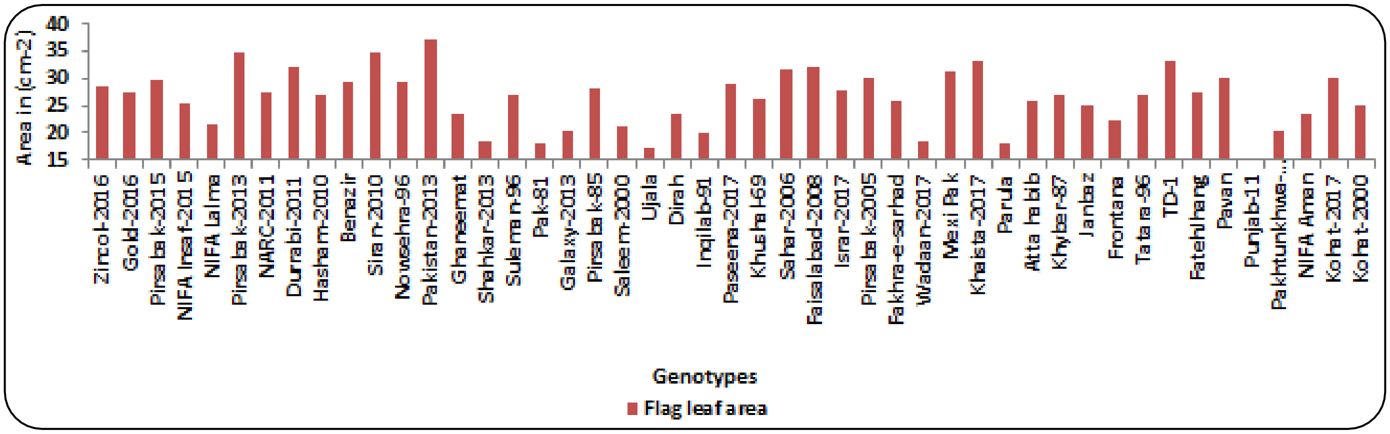

Figure 4. Bar- graph representing the mean for flag leaf area of 47 wheat genotypes at Mansehra during 2018-19 cropping season.

Tiller m^{-2}

The number of tillers plant^{-1} is a fundamental character influencing both the grain yield as well as the biological yield of crop. Analysis of variance revealed non-significant differences amid genotypes, lines, checks, and the comparison among checks and lines for tillers plant^{-1} (Table 1). However, Shah *et al.* (2007) described significant differences between genotypes for the number of productive tillers meter^{-2}. Tillers meter^{-2} is a main factor contributing to yield often closely related with the number of productive spikes and the resulting grain yield (kg ha^{-1}). Different wheat genotypes frequently have varying capacities for tillering. Higher grain yield is the result of having more tillers per plant which promises the ideal plant population. Due to a poor evapo-transpiration rate, the temperature of the plant canopy rises under stress, and the development of tillers is either significantly decreased or occurs later, which ultimately leads to a low grain yield (Riaz, 2003). According to previous studies, the genotypes of wheat with the maximum number of tillers per plant produced the most grain and the maximum biological and grain yield (Aslam *et al.,* 2007; Abd-El-Mohsen *et al.,* 2012). Adjusted mean datafor tiller^{-2} are given in (Figure 5). Tiller m^{-2} ranged from 57 m^{-2} to 172 m^{-2} with the mean valueof 114 m^{-2}. Among lines, 31 and 16 out of 45 lines produced more tillers than Kohat-2017(85 tillers m^{-2}) and Kohat-2000 (108 tillers m^{-2}), respectively. Minimum tillers were noticed for Israr-2017 (57 m^{-2}), whereas maximum tillers were recorded for Frontana (172 m^{-2}). As a result, more tillering-capable genotypes are favored over those with the least tillers. As it is considerably upturn the grain and biological yields in wheat, the selection principle in wheat breading is more tillers per plant-1 (Inamullah *et al.,* 2006).

Grains spike^{-1}

Plant breeder's focus on developing different wheat genotypes with an improved number of grains spike^{-1} as this is a serious factor influencing wheat production and directly impacting the yield potential of a genotype. Number of grains spike^{-1} can serve as selection criteria for breeding new wheat varieties. The analysis of variance exhibited non-significant differences amid genotypes, lines, checks, and the comparison among checks and lines for this trait (Table 1). The recent result opposes the previous research conducted by Shah *et al.* (2007). For grains spike^{-1} they found notable variations among wheat genotypes. The adjusted mean data for grain spike^{-1} is given in (Figure 6). In wheat, grains spike^{-1} is seen as a favorable trait. Among wheat populations, Sharma and Garg (2005) found logical variation in the grain yield and spike^{-1} features. According to Majeed *et al.* (2011), there are significant paybacks in all yield- contributing traits especially grains spike^{-1}. The mean value was 44 grains spike^{-1} with a range of 28 to 60. Out of 45 lines, 26 and 28 produced more grains spike^{-1} than Kohat-2017 (41 grains) and Kohat-2000 (39 grains) to be precise. Whereas, Gold-2016 had the highest number of grains spike^{-1} (60 grains), Frontana had the lowest number of grains spike^{-1} (28 grains). Research from the past and present has shown that grain spike^{-1} is a very important parameter and that grain yield depends exclusively on it. Therefore, Abd-El-Mohsen *et al.* (2012) found that raising grain spike^{-1} directly affects grain productivity.

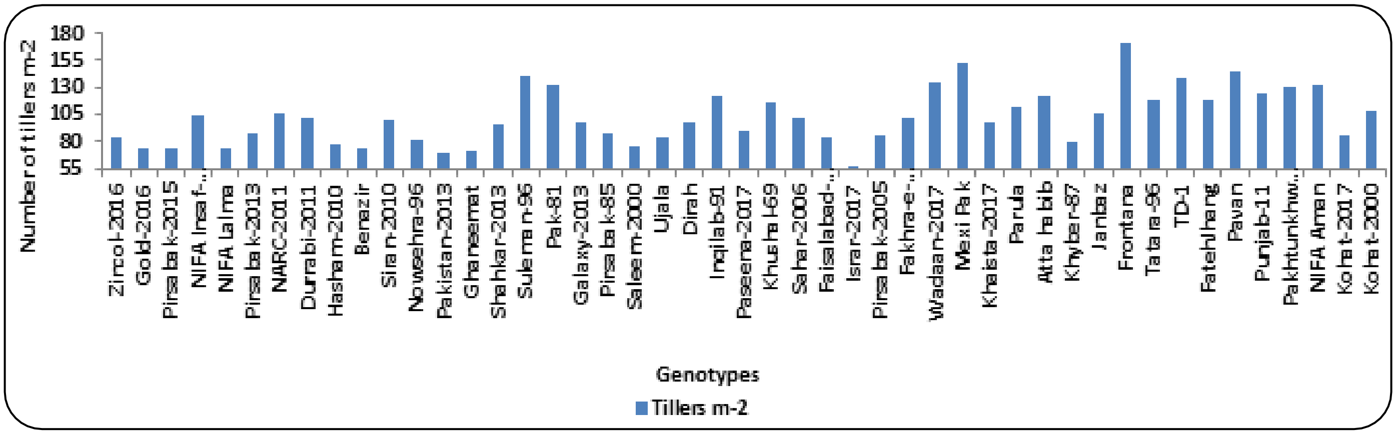

Figure 5. Bar- graph representing the mean for tillers m-2 of 47 wheat genotypes at Mansehra during 2018-19 cropping season.

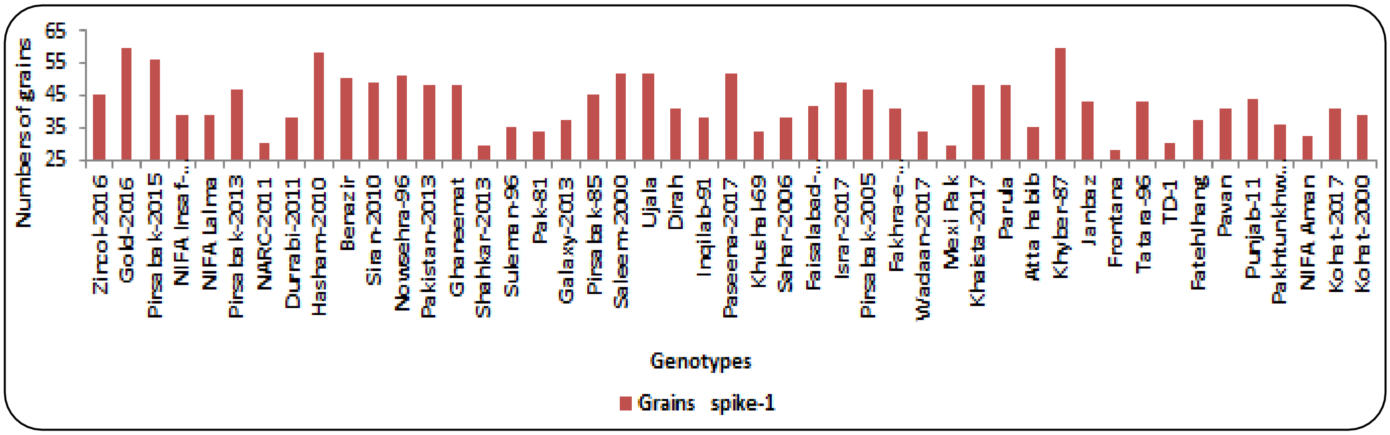

Figure 6. Bar- graph representing the mean for grain spike-1 of 47 wheat genotypes at Mansehra during 2018-19 cropping season.

Spike length

Large spikes are likely to produce more grains, which outcomes in a higher yield per plant, making spike length a crucial yield component. One of the important yield factors that affects grain yield is spike length (Sharma *et al.,* 2005). Analysis of variance exhibited significant differences between checks and checks vs. lines, but non-significant differences among genotypes and lines for spike length (Table 1). The outcomes of this tryout contrast with those of Hasnain *et al.* (2006), who described non-significant differences between genotypes for spike length. Adjusted mean data for spike length are given in (Figure 7). Spike length is considered as desirable trait in wheat. As usual, spike length might support 20-30% of the dry matter accumulated in the kernels in wheat. Singh *et al.* (2000) emphasized that wheat cultivars with longer spikes are commonly more productive and capable of yielding more grains a conclusion that is consistent with the outcomes of the present study. Spike length ranged from 6.9 cm to 12.5 cm with the mean value of 9.5 cm. Among lines, 5 and 38 out of 45 lines produced larger spikes than Kohat-2017 (11.5 cm) and Kohat- 2000 (9.3 cm), respectively. The findings of Akbar *et al.* (2009), who examined spike length in wheat genotypes came closer that selection in late segregating generations is expected to produce new varieties with improved spike length provide more support for spike length. Khushal-69 had the smallest spike length (6.9 cm), while Israr-2017 had the longest (12.5 cm). Significant variations in spike length and yield-related attributes were found between the genotypes of lines and checks by Sattar *et al.* (2018). Wheat genotypes with longer spike lengths may be used as possible candidates in future breeding programs conferring to Kumar *et al.* (2003).

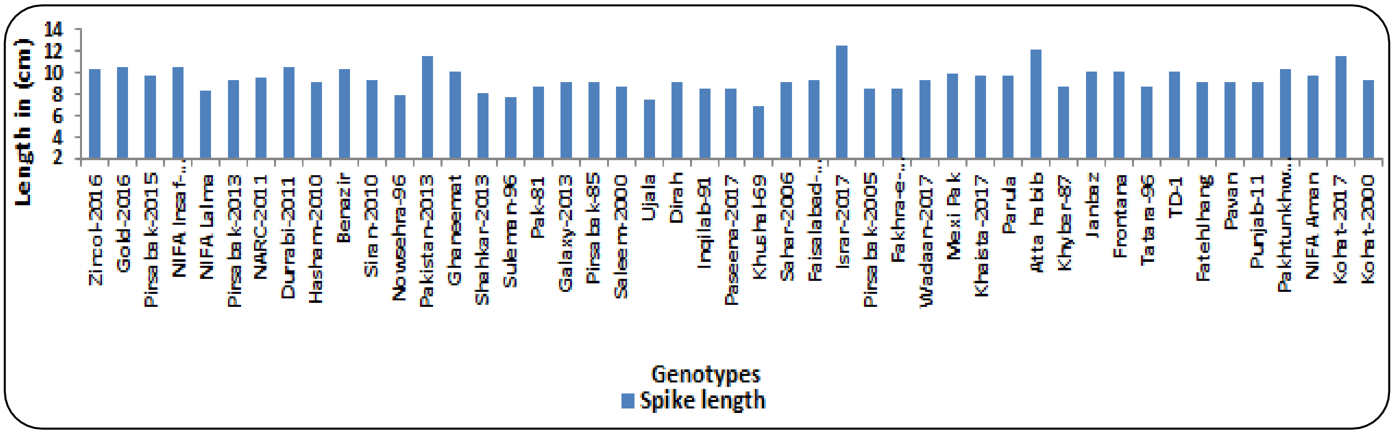

Figure 7: Bar- graph representing the mean for spike length of 47 wheat genotypes at Mansehra during 2018-19 cropping season.

1000 grain weight

1000 grain weight is a significant trait that promotes the grain yield and might be possibly exploited as selection criteria for high wheat productivity. According to Azam *et al*. (2013), the output and adaptation rate of assimilates during the grain formation process are main factors determining this vital yield trait in wheat. Analysis of variance showed significant differences between Genotypes, lines, checks, and checks vs. lines for 1000 grain weight (Table 1). Grain yield is influenced by 1000 grain weight which is a degree of selection used to choose good genotypes of wheat. Adjusted mean data for 1000 grain weight is shown in (Figure 8). 1000 grain weight is reflected as a desired character in wheat. 1000 grain weight ranged from (40 g) to (70 g) with the mean value of (55 g). Among lines, 3 and 29 out of 45 lines produced bold grains than Kohat-2017 (61 g) and Kohat-2000 (49 g), respectively. Minimum value of 1000 grain weight was noticed for Pavan (40 g), whereas maximum value of 1000 grain weight was recorded for NIFA-Lalma-2013 (70 g). However, based on the 1000 grain weight, Sarkar *et al.* (2002) determined that lines can only be beneficial because their effects are more durable in heredity. As a result, these lines would be assumed in future breeding schemes for crop development. According to earlier studies grain output is primarily based on 1000 grain weight, and wheat cultivars varied greatly in seed index (Awan *et al.,* 2005; Akbar *et al.,* 2009).

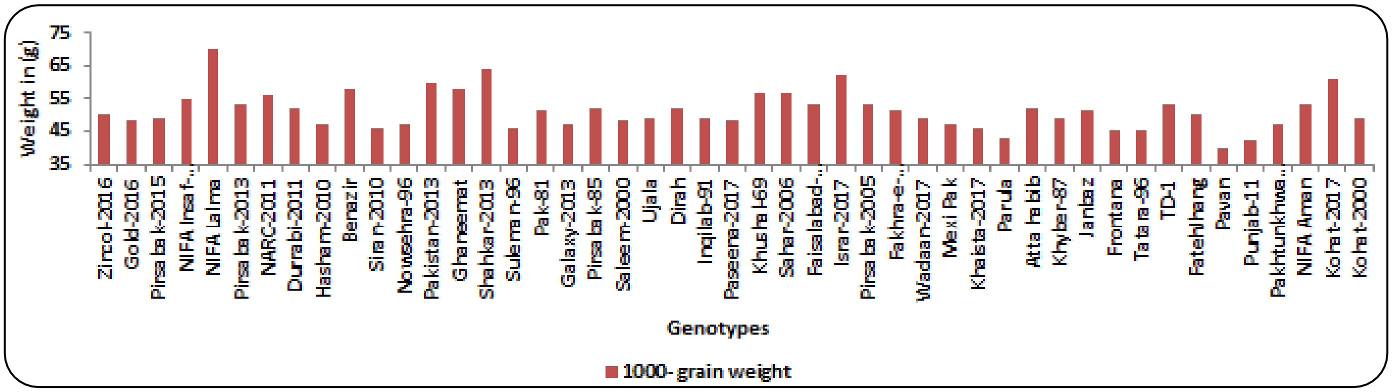

Figure 8. Bar- graph representing the mean for 1000- grain weight of 47 wheat genotypes at Mansehra during 2018-19 cropping season.

Grain yield

In order to accomplish the population's food demand plant breeders are primarily concerned with producing high-yielding, disease-resistant cultivars that either directly or indirectly improve grain yield a complex trait. The main concern in wheat breeding schemes is genotype differences for grain yield and yield-linked attributes (Talebi *et al.,* 2009). The analysis of variance revealed non-significant differences between genotypes, lines, checks, and the assessment of checks versus lines for grain yield plot^{-1} (Table 1). These results highlight the significant influence of environmental factors on the genetic performance of wheat genotypes for grain yield (g plot^{-1}). The results of current study are in distinction with the prior outcomes of Shah *et al*. (2007). They described significant differences between genotypes for grain yield. Adjusted mean data for grain yield plot^{-1} are given in (Figure 9). Grain yield plot^{-1} is considered a desirable trait in wheat. Grain yield plot^{-1} ranged from (165 g) to (250 g) with the mean value of (208 g). The grain yield is a prime objective of any research program. Among lines, 29 and 30 out of 45 lines produced higher grain yield than Kohat-2017 (210 g) and Kohat-2000 (208 g). Lowest grain yield plot^{-1}was noticed for Galaxy-2013 (1165 g), whereas maximum grain yield plot^{-1} was recorded for Pavan (250 g). Khalil *et al.* (2008) also presented their data clarifying those additional yield attributes such as; spike length, tiller m^{-2}, and spikelets spike^{-1} primarily governed and controlled grain output. According to Ingle *et al.* (2018), improving yield attributed traits and closely fixing the component qualities can also effectively increase yield.

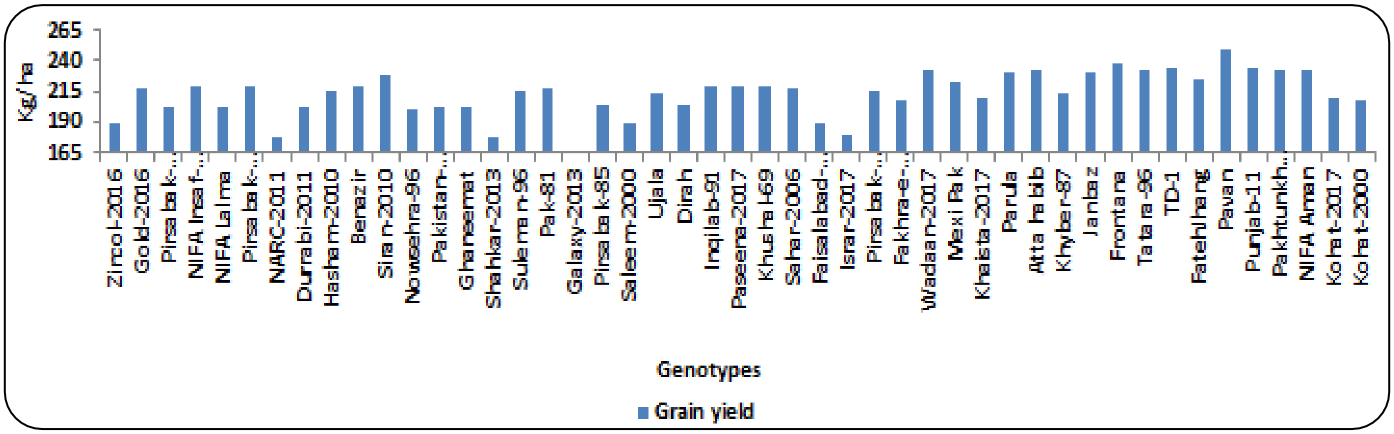

Figure 9: Bar- graph representing the mean for grain yield of 47 wheat genotypes at Mansehra during 2018-19 cropping season.

Stripe rust prevalence

At the peak stage data on the host's response to stripe (yellow) rust disease was documented in experimental trail on 47 bread wheat genotypes at Agriculture Research Farm, Hazara University Mansehra, Pakistan during 2018−19 crop season is given below (Table 2).

Table 2.Responses of 47 bread wheat genotypes against yellow rust at Mansehra during 2018-19.

S. No	Response	Germplasm
1	Immune	Zincol, Pirsabak-2015, Wadan 2017.
2	Resistant	Pirsabak-2013, Pirsabak-2005, Khaista-2017, Frontana.
3	Mod. Resistant	Gold-2016, NIFA-Lalma, NIFA-Insaf, Pakistan-2013, Shahkar-2013, Saleem-2000, Tatara-96, Pavan, Kohat-2017.
4	Mod. Resistant-resistant	Suleman-96, Pirsabak-85, Ujala, Dera-98, Paseena-2017, Khushal-69, Faisalabad-2008, Parula, TD-1, NIFA-Aman.
5	Mod. Susceptible-susceptible	NARC-2011, Dhurabi-2011, Ghanemat-IBGE,Pak- 81, Seher-2006, Israr-2017, Fakhre Sarhad, Atta-Habib, Khyber-87, Janbaz, Pakhtunkhwa-2015, Kohat-2000.
6	Mod. Susceptible	Fatehjhang.
7	Susceptible	Hasham-2010, Benazir, Siran-2010, Nowshera-96, Galaxy-2013, Inqilab-91, MexiPak, Punjab-2011.

Terminal reaction of stripe rust

Yellow rust data of 47 bread wheat genotypes i.e. terminal reaction are shown in (Table 2). Based on terminal reaction, three varieties viz. Zincol, Wadan-2017 and Pirsabak-2015 showed immune (0) reaction, whereas four varieties viz. Pirsabak-2013, Pirsabak-2005, Khaista-2017 and Frontana depicted resistant (R) reaction, nine varieties viz. Gold-2016, NIFA-Lalma, NIFA-Insaf, Pakistan-2013, Shahkar-2013, Saleem-2000, Tatara-96, Pavan and Kohat-2017. Likewise, 10 varieties viz. Suleman-96, Pirsabak-85, Ujala, Dera-98, Paseena- 2017, Khushal-69, Faisalabad-2008, Parula, TD-1 and NIFA-Aman, whereas Fatehjhang showed moderately susceptible (MS) reaction.

Similarly, 12 genotypes exhibited moderately susceptible to susceptible (MSS) viz. NARC-2011, Dhurabi-2011, Ghanemat-IBGE, Pak-81, Seher-2006, Israr-2017, Fakhre Sarhad, Atta Habib, Khyber-87, Janbaz, Pakhtunkhwa-2015 and Kohat-2000. Furthermore, eight varieties viz. Hasham-2010, Benazir, Siran-2010, Nowshera-96, Galaxy-2013, Inqilab-91, MexiPak and Punjab-2011.

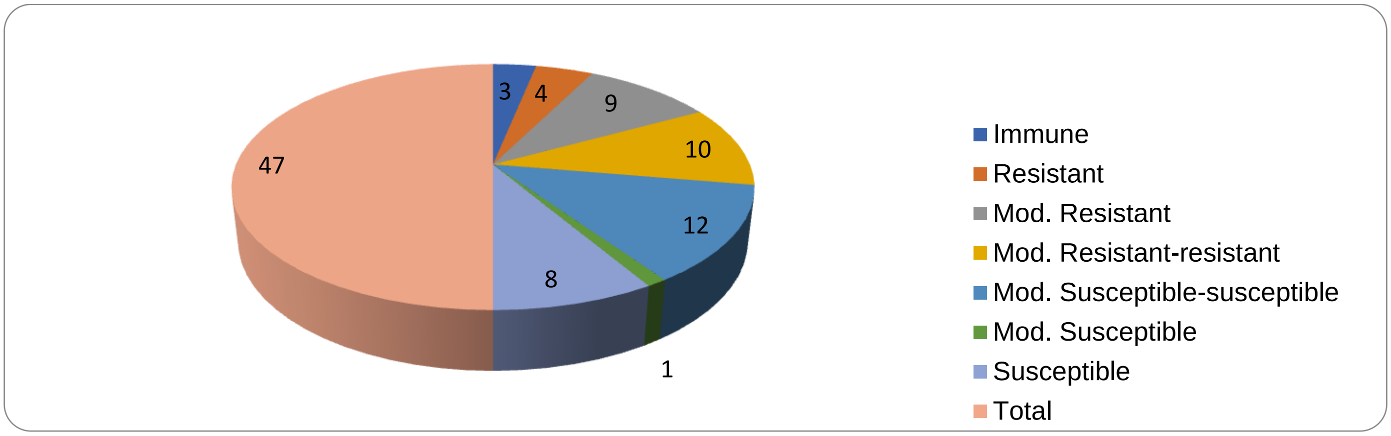

Figure 10. Graphical demonstrating of 47 bread wheat genotypes against Yellow rust at Mansehra during 2018-19.

Coefficient of infection of stripe rust

The yellow rust data of 47 bread wheat genotypes i.e. coefficient of infection is shown in (Figure 11). Based on coefficient of infection (CI), 17 varieties exhibited CI ranged amid 0-20 and were confirmed as extremely resistant viz. Pavan, Frontana, Wadaan-2017, Tatara-96, NIFA Aman, Parula, Fateh Jhang, Pirsabak-2013, Paseena-2017, Khushal-69, Gold-2016, Pirsabak- 2005, Ujala, Khaista-2017, Kohat-2017, Pirsabak-2015, Pakistan-2013 Zincol-2016, Faisalabad-2008 and Shahkar-2013. Twelve varieties expressed CI between 21- 40 and were declared as moderately resistant i.e. TD-1, Atta Habib, Pakhtunkhwa-2015, NIFA Insaf-2015, Suleman-96, Khyber-87, Kohat-2000, Pirsabak-85, NIFA Lalma-2013, Ghaneemat-IBGE, Israr-2017 and NARC-2011. Likewise, nine varieties showed CI between 41-60 and declared as moderately susceptible viz. Janbaz, Inqilab-91, Pak-81, Sehar-2006, Hasham-2010, Fakhra-e-Sarhad, Dera-98, Durrabi-2011 and Saleem-2000, whereas six varieties expressed CI between 61-80 and declared as susceptible i.e. Punjab-11, Siran-2010, Mexi-Pak, Benazir, Nowsehra-96 and Galaxy-2013.

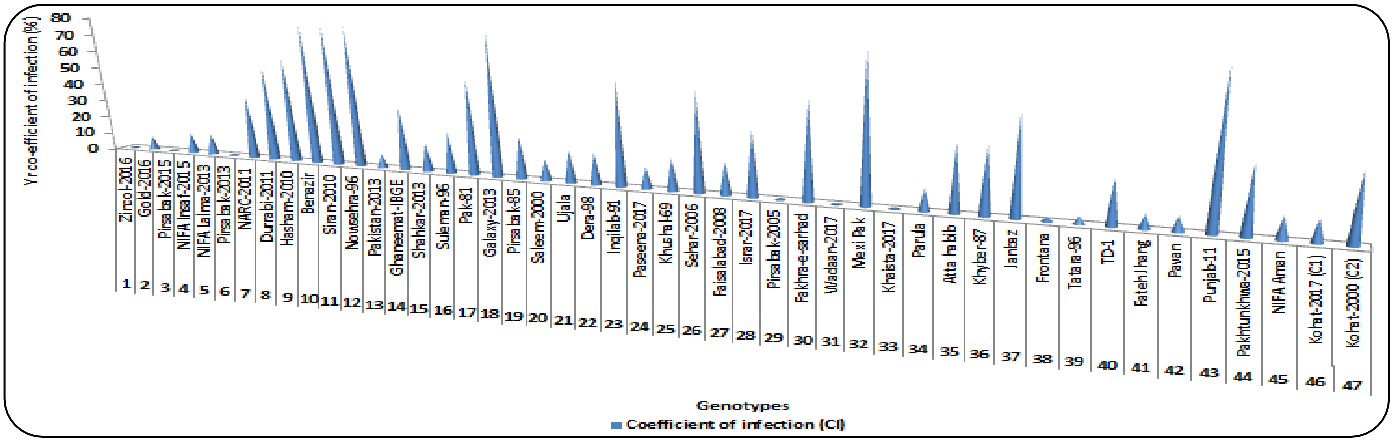

Figure 11: Graphical demonstration of co-efficient of infection (CI) of 47 wheat genotypes at Mansehra during 2018-19.

Stripe rust, a damaging wheat disease caused by P. striiformis f. sp. tritici (Pst), can result in a wide-ranging loss of wheat yield (Beddow *et al.,* 2015). In recent times, there have been reports of small epidemics in South Asia, East Asia, Australia, and North America (particularly the Pacific Northwest). In the 2018−19 growing season, a set of 47 bread wheat genotypes including two check cultivars i.e. Kohat-2000 (C1) and Kohat- 2017 (C2) were field tested during 2018-2019 crop season at Agricultural Research Farm, Hazara University Mansehra, Pakistan. It is important to appraise the virulence of Pst populations for the enclosure of potential resistance genes in the elite types in order to control the disease and prevent yield losses. Even after the resistant gene is introduced into superior germplasm new races of the rust pathogen appear a few years later removing the resistance and causing major epidemics of stripe rust. For instance from 2002 to 2004 Yr27 was a commonly used source of resistance in wheat cultivars; however, it became vulnerable due to the introduction of new pathogenic races in India and Pakistan (Sharma *et al.,* 2013). The Yr10 gene has been found to be racially specific and effective against all races in China, Iran, Pakistan, and the United States. (Bux, 2012). Because of the growing occurrence of Pst and the lack of disease resistance genes in wheat further investigation is requisite to identify and characterize new resistance genes that might be used to slow down the degradation of the resistance that is already present in wheat germplasm (Wang *et al.,* 2002).

Table 3. Terminal reaction of 47 wheat genotypes during 2018-19 growing season.

S. No	Genotype	Terminal reaction	S. No	Genotype	Terminal reaction
1	Zincol-2016	0	25	Khushal-69	30M
2	Gold-2016	20MR	26	Sehar-2006	60MSS
3	Pirsabak-2015	0	27	Faisalabad-2008	30M
4	NIFA Insaf-2015	30MR	28	Israr-2017	40MSS
5	NIFA Lalma-2013	30MR	29	Pirsabak-2005	5R
6	Pirsabak-2013	5R	30	Fakhra-e-sarhad	60MSS
7	NARC-2011	40MSS	31	Wadaan-2017	0
8	Durrabi-2011	60MSS	32	Mexi Pak	80S
9	Hasham-2010	60S	33	Khaista-2017	5R
10	Benazir	80S	34	Parula	20M
11	Siran-2010	80S	35	Atta habib	40MSS
12	Nowsehra-96	80S	36	Khyber-87	40MSS
13	Pakistan-2013	20MR	37	Janbaz	60MSS
14	Ghaneemat-IBGE	40MSS	38	Frontana	10R
15	Shahkar-2013	40MR	39	Tatara-96	10MR
16	Suleman-96	40M	40	TD-1	40M
17	Pak-81	60MSS	41	Fateh Jhang	10MS
18	Galaxy-2013	80S	42	Pavan	20MR
19	Pirsabak-85	40M	43	Punjab-11	80S
20	Saleem-2000	30MR	44	Pakhtunkhwa-2015	40MSS
21	Ujala	30M	45	NIFA Aman	20M
22	Dera-98	30M	46	Kohat-2017 (C1)	30MR
23	Inqilab-91	60S	47	Kohat-2000 (C2)	40MSS
24	Paseena-2017	20M			

CONCLUSIONS AND RECOMMENDATION

The findings of this study hold significant implications for both wheat breeding programs and farming practices, particularly in regions prone to stripe rust like Mansehra. By identifying genotypes with high yield potential and strong resistance to yellow rust, the study contributes to sustainable wheat production and food security. Below is a detailed discussion of the broader impact of the results:

Significant differences were observed among genotypes for days to heading and 1000-grain weight. Yellow rust data showed that out of 47 genotypes, 20 lines showed CI values between 0 to 20 (Resistant), 12 lines depicted CI values between 21 to 40 (Moderately resistant), 9 lines exhibited CI values between 41-60 (Moderately susceptible) whereas 6 lines showed ACI values between 61 to 80 (Susceptible). Based on yield and disease data, 17 genotypes viz. Pavan, Frontana, Wadaan-2017, Tatara-96, NIFA Aman, Parula, Fateh Jhang, Pirsabak-2013, Paseena-2017, Khushal- 69, Gold-2016, Pirsabak-2005, Ujala, Khaista-2017, Kohat-2017, Pirsabak-2015 and Pakistan-2013 were found high yielding and disease resistant and thus could be recommended for general cultivation in Mansehra region. The identification of high-yielding and stripe rust-resistant genotypes represents a significant step toward sustainable wheat production. These findings not only address the immediate challenges faced by farmers in Mansehra but also provide valuable resources for breeding programs aimed at combating wheat rusts globally. By promoting the adoption of these genotypes this study contributes to enhancing wheat productivity, reducing disease-related losses, and ensuring long-term agricultural sustainability.

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AUTHOR CONTRIBUTIONS

All authors contributed equally to this research.

COMPETING OF INTEREST

The authors declare no competing interests.

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