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CHARACTERIZATION OF ADVANCED SEGREGATING POPULATION OF WHEAT FOR FUNGAL DISEASE AND LODGING IN UPPER HAZARA REGION

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Abstract

Wheat is an important cereal crop and cultivated for staple food across the globe. Wheat germplasm resources show huge diversity for important fungal disease and lodging, which provides a valuable resource for gene introgression and trait improvement in elite cultivars. In the present study biparental wheat populations (F4 segregants) were evaluated for fungal disease and lodging under the climatic conditions of Mansehra. Interestingly, the F4 segregants showed a wide range of variability for fungal disease and lodging, suggesting the presence of multiple genes controlling these traits. These segregants can be used as source material in the regional wheat breeding programs. Based on above results the lines F4-2-71 and F4-5-44 depicted resistance (R) to yellow rust, check variety Fahim-19, F4-2-71, F4-1-5 were found resistant to powdery mildew while genotypes F4-4-9(0), F4-4-23(0),F4-4-29(0), F4-4-64(0), F4-4-15(0), F4-8-6(0), F4-8-24(0), F4-8-03(0), F4-11-03(0), Fateh Jhang(0), F4-1-31(0) expressed lodging resistant. These lines performed better, which could be further exploited for improvement in yellow rust, powdery mildew and lodging resistance.

Key words: Biparental populations, Fungal disease, Lodging, Segregants, Variability.

Introduction

Wheat (*Triticum aestivum* L. 2n = 6x = 42), a member of the *Poaceae* family, is one of the world's most significant staple foods. It accounts for17% of crop acreage, feeding around 40% of the world's population, and providing 20% of total food calories and protein in human nutrition (Peng *et al*., 2011). It is a refined source of macronutrients and micronutrients required for human nutrition. Wheat is the most affordable source of proteins, fibers, minerals and vitamins, and play a significant role in the global food grain trade (Rahman *et al*., 2016; Chaudhary *et al*., 2021). Pakistan is ranked 7th in terms of wheat production (Anon., 2023). In Pakistan, the production of wheat was 27.634 million ton million tons during 2022-2023 and planted on 9,043 thousand hectares (Anon., 2022-23). In Khyber Pakhtunkhwa, total of 27.63 million tons wheat was produced during 2022-2023 (Anon., 2023).

Wheat crops experience a number of abiotic and biotic stresses causing a significant loss in yield and quality (Khan *et al*., 2016). Among the biotic stresses, diseases are the major cause of yield losses. It has been estimated that 81 bacterial, 40 fungal and 32 viral diseases infect wheat (Bonjean & Angus, 2001). Among the fungal diseases, rust and powdery mildew are more prevalent causing sever damages to the crop. Rusts mostly attack stems and leaves of specific varieties and genera (Agrios, 2005). Yellow rust caused by fungus *Puccinia striiformis* f. sp. *tritici*, is the most common & destructive fungal disease that affects wheat, especially in regions with cold and humid environments (Rani *et al*., 2018). Yellow rust causes considerable output losses (50–100%) in cereal crops causing shriveled grain from early growth stages through maturity (Waqar *et al*., 2018). In Khyber Pakhtunkhwa, wheat cultivars like Mexipak, Pak 81, and Pirsabak 91 succumbed to yellow rust disease due to the emergence of new virulent races, causing a severe epidemic in 1994-1995 with a 40% grain yield decrease (Mirza *et al*., 2012). The introduction of Inqalab-91 as a replacement of Pirsabak-85 and Pak-81 on 80% of the land presenting the risk of crop loss to emerging yellow rust races (Afridi *et al*., 2019). The fungal disease powdery mildew cause by *Blumeria graminis*, which affects wheat, causes significant economic loss in production due to the pathogen's characteristics that encourage rapid spread and adaptation, such as its short life cycle and the ease with which airborne spores can be transported over long distances (Kang *et al*., 2020). *B. graminis* is an ascomycete that is a member of the *Erysiphales* (Takamatsu, 2004). Powdery mildew ranks sixth among the top 10 fungal pathogens affecting wheat and stands as the eighth leading cause of global yield loss (Dean *et al*., 2012, Savary *et al*., 2019). In the past, breeding programs in Pakistan has little consideration to utilize powdery mildew resistance in improved genetic stocks and thus genetic improvement of wheat varieties against powdery mildew was limited. This was mainly due to little information on distribution of the disease and the regional risks of epidemics across Pakistan (Khan *et al*., 2019). Despite the disease's presence in the northern, cold-climate wheat-growing regions, little research has been done in Pakistan to create genetic improvements against powdery mildew (Khan *et al*., 2021).

One of the most chronic constraints to crop production is the grain yield reduction near the crop harvest stage by lodging worldwide (Shah *et al*., 2019). Lodging refers to stem breaking type and stem bending type (stem lodging) or root lodging (anchorage failure) of the plants and is one of the most concerning problems faced by the farmers worldwide (Mulsanti *et al*., 2018, Zuo *et al*., 2017). Fischer & Stapper (1987) conducted artificial lodging experiments in northwest Mexico, inducing lodging at varying angles at different stages of crop development. However, such controlled conditions do not mimic the natural lodging patterns observed under typical field conditions. Lodging, a serious problem under irrigated and high input N fertility conditions, interferes with water and nutrient uptake, reduces effective light interception, decreases grain fill, provides a more conducive environment for disease and increases harvesting costs and losses (Tripathi *et al*., 2004).

Owing to the above discussion, it can be concluded that fungal diseases and lodging are important constraints in the optimal wheat productivity. Therefore, we aimed for our research to analyze the effect of yellow rust, powdery mildew and lodging in the advanced segregating populations to identify tolerant lines of wheat.

Material and Methods

Location and materials: The current experiment was carried out in the 2022–2023 crop season at the Agriculture Research Farm, Hazara University Mansehra, Khyber Pakhtunkhwa, Pakistan (34.4211° N, 73.2502° E). Sixty advanced segregating lines (F4 generation) and three checks cultivars (NIA Sunheri, FatehJhang and Fahim-19) were used. The field experiment was laid down in Augmented design. The experimental field consists of two blocks, each having 30 test lines (1 row-1m long) along with 3 checks in each block with row-to-row distance of 25 cm. The recommended agronomic practices were carried out for healthy crop stand. The crop was grown under uniform conditions to minimize the environmental influence in the genotype expression.

Diseases scoring: Rust scoring recorded as (1) severity; that is, the percentage of tissue rusted, on a Modified Cobb Scale from 0 to 100% (Peterson *et al*., 1948) and, (2) host reaction (HR), measured as I, R, MR, MRMS/M, MS and S, (Singh, 1993) based on the symptoms as mentioned in table 1. The severity in percentage was multiplied with a constant value for each type of HR (Table 1) to get a coefficient of infection (CI) (Safavi & Farzad, 2012, Ali & Hodson, 2017).

Coefficient of infection = Percent severity x Constant of HR

For powdery mildew scoring double digit scale (D1D2) used. The scoring was denoted on plant using the 0-9 scale (Saari & Prescott, 1975). For each accession, disease severity percentage was calculated according to Sharma & Duveiller (2007) based on following formula:

$$\text{Disease severity (\%)} = (D1/9) \times (D2/9) \times 100$$

where; D1 indicates vertical disease progress on plant, D2 indicates severity calculated as diseased leaf area. Whereas the adult plant reaction was categorized based on severity as follows:

Resistance (R) = 1-10%, Moderately Resistance (MR) = 11-30%,
Moderately susceptible (MS) = 31-50%,
Susceptible (S) = 61% and above, Highly Susceptible (HS),
Lodging scoring:
Visual assessment of lodging is done by assigning a lodging score to a crop, based on the spatial extent and angle of lodging (Fischer & Stapper, 1987).

Statistical Analysis

Recorded data was analyzed by using appropriate statistical software (AGD-Package for Augmented design by CIMMYT). This software was chosen for its specialized features designed to handle augmented designs effectively, ensuring accurate and reliable statistical analysis tailored to the specific experimental setup employed in the study.

Results

The field observation revealed that the advanced segregating lines and check cultivars showed a varied response to the fungal diseases and lodging. In the case of diseases, a considerable number of lines were tolerant or moderate tolerant.

Yellow rust data of 63 wheat genotypes i.e. terminal reaction and coefficient of infection (CI) are given in Table 2: Based on terminal reaction, four advance lines: F4-9-28, F4-9-42, F4-10-3, F4-11-26 showed immune (0) reaction, whereas two advance lines viz. F4-2-65, F4-5-44 depicted resistant (R) reaction where as two susceptible lines are F4-8-03, F4-8-09.

Yellow rust data showed that out of 63 genotypes, 54 lines showed CI values between 0 to 20 (Resistant), 6 lines depicted Coefficient of infection (CI) values between 21 to 40 (Moderately resistant), 2 lines exhibited Coefficient of infection (CI) values between 41-60 (Moderately susceptible) whereas 1 line showed CI values between 61 to 80 (Susceptible) as given in (Table 2).

The lodging score revealed that genotypes have varied loading response. The lodging was scored in in percentage (%). Among the 63 genotypes, 11 genotypes were highly stable and resistant to lodging with 0% lodging score. Minimum value for lodging percentage were recorded for genotypes F4-4-9(0), F4-4-23(0),F4-4-29(0), F4-4-64(0), F4-4-15(0), F4-8-6(0), F4-8-24(0),F4-8-03(0),F4-11-03(0), Fateh Jhang(0), and F4-1-31(0) whereas maximum lodging percentage were noticed for genotypes F4-1-5(100), and F4-7-10(100).

Among the 63 genotypes, check variety Fahim-19, F4-2-71, and F4-1-5 were found resistant to powdery mildew. Whereas genotypes exhibited moderate resistance are check NIA Sunheri, Fateh Jhang, F4-1-24, F4-1-09, F4-1-20, F4-1-31, F4-3-48, F4-3-22, F4-4-64, F4-5-16, F4-8-09, F4-10-46, F4-11-26, F4-11-03, F4-12-42, and F4-12-13. 33 while susceptible lines are F4-3-35, F4-4-15, F4-2-66, F4-5-44, and F4-5-50. Out of 63 genotypes, 3 genotypes are Resistant, 16 are moderate resistance, moderately susceptible lines are 39 while susceptible lines 05 as shown in Table 3.

Table 1. Field response of host plant to wheat rusts used during disease scoring in the field.

Terminal reaction	Description	Observation	Response value
No Disease	Immune, No visible infection	I	0
Resistant	No uredia present, visible chlorosis or necrosis	R	0.2–0.10
Moderately Resistant	Small uredia surrounded by chlorotic/necrotic areas	MR	0.4–0.25
Moderately Resistant – Moderately susceptible	Combination of both MS and MR.	MR-MS/M	0.6–0.50
Moderately susceptible	Uredia medium size with no necrotic margins, possibly some distinct chlorosis	MS	0.8–0.75
Susceptible	Large are uredia with no necrosis and little or no chlorosis	S	1.0

Table 2. Yellow rust data showing terminal reaction and coefficient of infection (CI) and lodging percentage of wheat during 2022-23.

Genotypes	Terminal reaction	Coefficient of infection (CI)	Lodging percentage	Genotypes	Terminal reaction	Coefficient of infection (CI)	Lodging percentage
F4-1-24	5M	03	40	F4-4-33	5M	03	30
F4-1-5	5M	03	100	F4-7-11	10MSS	09	20
F4-1-09	5M	03	80	F4-7-52	40MSS	36	30
F4-1-20	5MS	04	80	F4-8-6	20MS	16	0
F4-1-31	5M	03	10	F4-8-24	30MSS	27	0
F4-2-65	10MS	08	20	F4-8-03	60S	60	0
F4-2-71	5R	01	20	F4-8-23	10MS	08	20
F4-2-66	30MS	24	20	F4-8-09	80S	80	50
F4-2-60	20M	12	10	F4-9-20	10MR	04	80
F4-2-43	30M	18	40	F4-9-37	10MR	04	90
F4-3-48	5MR	02	70	F4-9-09	20M	12	50
F4-3-35	5M	03	50	F4-9-28	0	00	70
F4-3-44	5MR	02	50	F4-9-42	0	00	10
F4-3-22	20MR	08	40	F4-10-31	0	00	20
F4-3-02	20MS	16	40	F4-10-19	30M	18	10
F4-4-9	5M	03	00	F4-10-46	10MS	08	50
F4-4-23	5M	03	00	F4-10-47	10M	06	70
F4-4-29	5MS	04	00	F4-10-48	10MS	08	10
F4-4-64	20M	12	00	F4-11-26	0	00	20
F4-4-15	40MSS	36	00	F4-11-11	10M	06	10
F4-5-48	20M	12	30	F4-11-03	5MR	02	0
F4-5-44	10R	02	30	F4-11-19	5M	03	20
F4-5-50	10MR	04	10	F4-11-07	10MS	08	20
F4-5-16	5M	03	30	F4-12-42	40MSS	36	10
F4-5-47	10MS	08	40	F4-12-04	5M	03	30
F4-6-22	30M	18	40	F4-12-09	30MSS	27	50
F4-6-1	20MSS	18	50	F4-12-13	10M	06	40
F4-6-9	5M	03	30	F4-12-33	5M	03	30
F4-6-4	30M	18	20	NIA Sunheri	60MSS	52	33
F4-6-29	20MS	16	10	Fateh Jhang	5MS	04	00
F4-7-49	10MS	08	70	Fahim-19	10MR	04	23
F4-7-10	20MS	16	100				

Discussion

Abiotic and biotic stresses are a constant threat to the crop production and food security. Wheat crop experience biotic and abiotic pressures particularly at the reproductive stage, which severely hinder potential productivity and affect quality. It is important to thoroughly survey the germplasm and identify resistant genetic resources for stable crop production (Khan *et al*., 2016). In the present study, advanced segregating population (F4) was evaluated in the natural environment to identify stable combinations resistant/ tolerant to fungal disease and lodging. This indicated greater genetic variability among the genotypes for the studied traits which can be exploited for the development of yellow rust, powdery mildew and lodging resistance wheat lines.

Reportedly, yellow rust causes severe losses to the wheat crop and has global occurrence. Its incidence occurs usually at boot stage and low temperature. Genetic resistance is the far most effective strategy for the control of yellow rust. Identification of resistant resources and their introgression in the elite cultivars is important in wheat breeding. In the present study, we evaluated 60 advanced segregating lines and observed its reaction to yellow rust in natural conditions. Interestingly it was found that four lines were resistant and others showed varied degree of tolerance. The presence of complete resistance and tolerance indicates the quantitative nature of resistance, and the presence of multiple alleles with quantitative contribution to the overall response to the infection. Our investigation depicted the presence of diversity among the tested genotypes for yellow rust resistance which could provide valuable germplasm for breeding for disease resistance program. Our findings concede with the previous reports described by Shehab-Eldeen & Abou-Zeid (2020), Khodarahmi *et al*., (2014), Khaivi *et al*., (2017), Rani *et al*. (2018), Hawary *et al*., (2022) and KOC *et al*., (2023).

One of the most chronic constraints to crop production is the grain yield reduction near the crop harvest stage by lodging worldwide (Shah *et al*., 2019). Maximum line showed resistance to lodging. Our findings are similar to the results of Cruz *et al*., (2005) and Chavez *et al*., (2016).

Out of 63 genotypes, 3 genotypes are Resistant, 16 are moderate resistance, moderately susceptible lines are 39 while susceptible lines 05 to powdery mildew. Our investigation depicted the presence of diversity among the tested genotypes for powdery mildew resistance which could provide valuable germplasm for breeding for disease resistance program, Gerechter-Amita & Van Silfhout (1984), Aly *et al*., (2023), Xiaowen *et al*. (2008). Mohler *et al*., (2011) and Khan *et al*., (2019. Pietrusinska & Tratwal. (2020) also favor immunological breeding and according to them it has now become an essential part of modern farming methods.

Table 3. Powdery mildew data of wheat during 2022-23.

Genotypes	Scoring (D1D2)	Severity %	Reaction	Genotypes	Scoring (D1D2)	Severity %	Reaction
F4-1-24	25	12	MR	F4-4-33	55	31	MS
F4-1-5	17	09	R	F4-7-11	55	31	MS
F4-1-09	55	31	MR	F4-7-52	57	43	MS
F4-1-20	53	19	MR	F4-8-6	75	43	MS
F4-1-31	53	19	MR	F4-8-24	57	43	MS
F4-2-65	55	31	MS	F4-8-03	39	33	MS
F4-2-71	15	06	R	F4-8-23	57	43	MS
F4-2-66	77	60	S	F4-8-09	37	26	MR
F4-2-60	39	33	MS	F4-9-20	75	43	MS
F4-2-43	55	31	MS	F4-9-37	55	31	MS
F4-3-48	37	26	MR	F4-9-09	57	43	MS
F4-3-35	59	56	S	F4-9-28	57	43	MS
F4-3-44	55	31	MS	F4-9-42	55	31	MS
F4-3-22	37	26	MR	F4-10-31	55	31	MS
F4-3-02	55	31	MS	F4-10-19	75	43	MS
F4-4-9	57	43	MS	F4-10-46	73	26	MR
F4-4-23	57	43	MS	F4-10-47	57	43	MS
F4-4-29	57	43	MS	F4-10-48	75	43	MS
F4-4-64	73	26	MR	F4-11-26	53	19	MR
F4-4-15	59	56	S	F4-11-11	57	43	MS
F4-5-48	55	31	MS	F4-11-03	37	26	MR
F4-5-44	77	60	S	F4-11-19	55	31	MS
F4-5-50	59	56	S	F4-11-07	55	31	MS
F4-5-16	37	26	MR	F4-12-42	35	19	MR
F4-5-47	75	43	MS	F4-12-04	57	43	MS
F4-6-22	75	43	MS	F4-12-09	39	33	MS
F4-6-1	55	31	MS	F4-12-13	37	26	MR
F4-6-9	75	43	MS	F4-12-33	39	33	MS
F4-6-4	57	43	MS	NIA Sunheri	35	19	MR
F4-6-29	57	43	MS	Fateh Jhang	37	26	MR
F4-7-49	55	31	MS	Fahim-19	13	04	R
F4-7-10	57	43	MS				

Conclusion

In the present study F4 segregants were evaluated for fungal disease and lodging resistance under the climatic condition of Mansehra, Pakistan. These traits exhibited wide range of variations with the segregants. These segregants can be used a source material in the regional wheat breeding programs. Based on above results F4-2-71, and F4-5-44 depicted resistant (R) to yellow rust, check variety Fahim-19, F4-2-71, and F4-1-5 were found resistant to powdery mildew while genotypes F4-4-9(0), F4-4-23(0),F4-4-29(0), F4-4-64(0), F4-4-15(0), F4-8-6(0), F4-8-24(0),F4-8-03(0),F4-11-03(0), Fateh Jhang(0), and F4-1-31(0) lodging resistant. These lines performed better, which could be further exploited for improvement in yellow rust, powdery mildew and lodging resistance.

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