

Screening for resistance against rust diseases in advanced wheat (*Triticum Aestivum* L.) genotypes

Abstract

Rust diseases cause significant losses to wheat production worldwide. Five newly evolved wheat genotypes along with three commercial wheat varieties were evaluated for resistance to rust diseases. Genotypes were screened at different locations in Pakistan through CDRI (Crop Diseases Research Institute) programme. The advanced genotypes and commercial varieties had different responses against rust (leaf, yellow and stem rust) infections. Two of the cross bred lines (NIA-10/8, ESW-9525) and a mutant MSH-5 showed resistance against leaf rust with desirable ACI (Average Coefficient of Infection) value (<9). The all five contesting advanced lines showed low intensity of stem rust disease with ACIs values 0.0, 0.2, 0.67, 0.13 and 5.0, respectively. However, genotypes NIA-10/8 and ESW-9525 were found resistant against all three rusts at different locations, also produced higher grain yield (4167kg ha^{-1}) and (3778kg ha^{-1}) respectively. Hence, could be used in future breeding programmes for disease resistance with higher yield.

Keywords: bread wheat, leaf, stem, stripe rust, resistance

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Introduction

Plant diseases are the major threat to the global food security, and have an ancient history of famines and destruction of economies. Rust diseases are among the destructive factors of wheat, can attack diverse grass species and result up to 60 percent yield losses for leaf, 30 per cent for stripe and 100 % for stem rust^{1,2} and 10% losses annually.³ In Canada and USA, stem rust epidemic caused great wheat losses of approximately 4.5 million tones.⁴ Due to the rapidly evolving nature of Ug99 several resistance genes originally described as effective are no longer functional.⁵ Over 5000 or more species of rust fungi have been reported.³

Wheat (*Triticum aestivum* L.) is one of the leading food source of Pakistan, while providing 30 percent dry matter and 60 percent calorie intake to the population of developing regions of the world. With the rising global population and decreasing arable land, wheat production and yield improvement became crucial.⁶⁻⁸ Increasing global population expected to cross 9 billion by 2050.⁹ Therefore, to fulfill the food demands of ever growing population, the food produced in developing countries has to be enhanced by 70 per cent till 2050,¹⁰ fundamentally from the same or even less area and water assets.¹¹ The Asian region expected to produce > 400 million tons of wheat by 2050. Rust diseases of wheat are among the ancient crop diseases known by human. Food insecurity is increasing day by day subject to the prevailing climatic changes.^{12,13} These changes attributed to raise the temperatures, fluctuations in rainfall, consequently catalyses the severity of rust diseases that are damaging these crops. Hence, unpredictable crop yield, and uncontrollable changes in markets, product prices and supply chain material.¹⁴ Although presently 58 stem rust resistance (Sr) loci have been recognized in wheat,⁵ just few were found functional particularly against the highly virulent Ug99¹⁵ and new variants.¹⁶⁻¹⁸ Markers based approaches are reliable to locate genes regulating the disease reaction. The bi-parental mapping populations have recently been used to relate phenotype driven knowledge to genotypic results acquired through molecular markers

in order to determine the numeral and locality of the resistance loci on the chromosome.^{19,20}

Disease reactions for the cereal rusts can be evaluated by either qualitative or quantitative manners, or both combined. Wheat is highly affected by three common rusts; stem rust (*Puccinia graminis* Pers. f.sp. *tritici* Eriks. & E. Henn); leaf rust (*P. triticea* Eriks); and stripe rust (*P. striiformis* Westend f.sp. *tritici*), these rusts have comparatively complex life cycles. The most visible attributes of their life cycle are the formation of uredinia and telia, allocating the foundation for the specific designation. Stem rust is characterized by the appearance of telia in black due to the black teliospores, leaf rust identified by the brown uredinia and stem rust appears yellow because of the yellow urediniospores on various plant parts. After developing new high yielding genotypes, material was handed over to CDRI for screening against rust diseases. To this end, various experiments were conducted in diverse regions of Pakistan, so that varieties could be evolved for resistance against rusts that are among the major hindrance for higher crop productivity.

Materials and methods

Five newly evolved bread wheat genotypes, 5 (ESW-9525 NIA-10/8,) and 3 mutants (MSH-3, MSH-5, MSH-36) were evaluated for resistance against rusts. Mutant genotypes were developed through radiation induced mutagenesis (gamma rays). Genotypes were developed at Nuclear Institute of Agriculture; NIA Tando Jam. Three check varieties were also evaluated for screening against rust diseases i.e. Kiran-95, NIA-Amber and Morocco. The objectives of screening were to determine the disease resistance in new and existing wheat varieties and to select disease resistant lines for future wheat breeding programmes. Genotypes were screened at different locations in Pakistan through CDRI, NARC Islamabad during the wheat cropping season 2012-13. The susceptible variety 'Morocco' was used as standard susceptible check at each location. For leaf rust these genotypes were evaluated at six sites viz., Karachi, Tandojam,

Sakrand, Thatta, Bhawalpur and Faisalabad. However, stem rust was evaluated at three locations in Sindh province, viz., Karachi, Tandojam, Thatta, although yellow rust was evaluated at Islamabad, Nowshera and Peshawar. Data on disease intensity was recorded from each location. Grain yield was measured after harvesting, threshing and weighing of grains of 2.4m² sample area which is then converted into kg ha⁻¹. Samples for 1000 grain weight were taken from the grain yield of each plot. Data were statistically analyzed using Analysis of Variance (ANOVA) for each character by statistical computer software “Statistix 8.1” and means were calculated followed by the Duncan’s multiple range (DMRT) tests.

Results and discussion

The analysis of variance was calculated for five genotypes (Table 1) (Table 2). Significant variation was noticed ($p < 0.01$) for the recorded traits, except the grain yield kg ha⁻¹. NIA-10/8 took more number of days to heading (78 days) and MSH-36 took minimum days to heading (63). MSH-36 was the earliest genotype with 117 days and maximum days to maturity were taken by ESW-9525 (126 days). Tallest height was achieved by NIA-10/8 (120 cm) whilst three genotypes (MSH-3, MSH-5, MSH-36) showed semi-dwarf stature, but ESW-9525 was under the range of tall-dwarf (108 cm) plant height. Selection for tall plants is reported to be helpful for biologically vigorous plants. Thousand grain weight is an important trait, variability among genotypes exists for production of higher 1000 grain weight. Maximum 1000 grain weight was obtained by the genotype NIA-10/8 (41.2 g) followed by the MSH-3 (40.7 g). However, lowest 1000-grain weight was shown by ESW-9525 (38.3 g). This genotype perform better under stressed conditions in other experiments, might be the reason for lowest 1000 grain weight and consequently lowest yield (3778 kg ha⁻¹) under normal environment. Maximum yield was attained by the genotype MSH-5 (4778 kg ha⁻¹) followed by the genotypes MSH-36 4695 and MSH-3 (4694 kg ha⁻¹). It is reported that 1000-grain weight is one of the major yield contributing trait, could be a reliable selection criterion for superior yielding genotypes.

Emerging new rust races are exhibiting their potential to adapt in extreme temperatures a phenomenon not observed before, constitute substantial losses to wheat globally. *Puccinia graminis* Pers. f. sp. *tritici* (pgt) contributes great losses to wheat produce.^{2,5,21,22} Here we report our findings for disease intensity (leaf, stem and yellow rusts) on wheat genotypes at various locations (Tables 3–6). Genotypes showed distinct response to different rusts (leaf, yellow and stem rust). Some genotypes showed highly resistant (R or MR type) reaction, while others showed MS type reaction. Two conventionally bred genotypes (NIA-10/8, ESW-9525) and one mutant MSH-5 showed

resistant reaction against leaf rust with desirable (< 9.0) ACI values (Table 4). Commercial variety (NIA-Amber) also showed resistant reaction to leaf rust disease at different locations of the country (Table 4). The infection level for leaf rust was higher at Karachi, Tandojam and Sakrand (ACI ranged from 0–60 MSS, 0–40 MSS, and 0–40 MSS respectively); but lower at Faisalabad (0–40 MRMS) and Bahawalpur (0–20 MSS). Leaf rust can cause heavy losses of up to 50% especially in a susceptible genotype because of its more frequent and widespread occurrence, its effect on total annual losses is more severe than other rusts (stem and stripe) worldwide.⁵

For stem rust, all five contesting advance lines showed low intensity of disease over all 3 locations with ACI values 0.0, 0.2, 0.67, 0.13, and 5.0, respectively (Table 5). Stem rust at Tandojam site did not appear, however it was observed at Karachi and Thatta sites. The ACI value for stem rust among wheat genotypes ranged from 0 to 22.7. For stem rust ESW-9525 (ACI-0) exhibited resistance at Karachi. However, all the advanced lines and varieties showed resistance at Tandojam. Moreover, 5 advanced genotypes ESW-9525, NIA-10/8, MSH-3, MSH-5, NIA-6/12 showed resistant at Thatta. Although, advance line ESW-9525 obtained ‘0’ ACI along with 3 varieties, other 4 lines and 02 varieties also obtained ACI under the desirable range of disease (Table 5). Although identification and utilization of reliable sources of resistance is tiresome, wheat germplasm with stable resistance is well recognized and documented.²³ Stem rust can cause drastic crop losses in a short time span at the end of the season. Developing resistant genotypes is one of the strategies to combat losses due to rust diseases in wheat producing regions of the world. Yellow rust (*Puccinia striiformis* f. sp. *tritici*) is important biotic factor limiting wheat (*Triticum aestivum* L.) yield in the country and globally.^{23–25} Severe impact imposed by this foliar disease in terms of yield reduction ranging from 10 to 70% has mold research into its vigorous virulence as indispensable for sustainable control.^{24,26} Due to wider spread of the disease, it causes 30 to 100% yield losses. For yellow rust, wheat genotypes were evaluated over 3 locations viz., Islamabad, Nowshera and Peshawar. Generally, the yellow rust was observed at all 3 locations with overall high severity average ACIs (Table 6). The overall lowest infection with high yellow rust resistance was found in NIA-10/8, ESW-9525 and NIA-Amber (ACIs 0.0, 1.0, 6.3 and 10.0 respectively). The highly susceptible reaction (93.3 ACIs) was recorded in Morocco (Table 6). The severity of yellow rust infection ranged from 0–90s at NARC, Islamabad, 0–80 at Nowshera and Peshawar locations. Additionally, its ability to mutate and reproduce sexually and asexually has made this disease more complex to tackle.^{27,28} Disease attack at the seedling stage results into grave losses, although at anthesis also effects root weight and grain.²⁵

Table 1 Parentage/pedigree of studied genotypes/varieties

S.No	Varieties/ Genotypes	Pedigree/parentage	Name of institute
1	ESW-9525	Kauz/Gen	NIA, Tandojam
2	NIA-10/8	Sha5/Weaver/3/Kauz//Kauz/Star//Khirmar	
3	MSH-3	Mutant (Kauz/Sarabz) 200Gy	
4	MSH-5	(Vorona/CNO79)//Soghat-90	
5	MSH-36	Vorona/CNO79// (Marvi-2000/Khirmar) 200Gy	

Table 2 Analyses of variance (ANOVA) of the data (mean squares) for yield and some yield associated traits in two bread wheat cultivars

Source of variation	DF	Days to heading	Days to maturity	Plant height (cm)	1000- grain weight	Grain Yield kg ha ⁻¹
Replications	2	0.2	3.4667	4.067	0.04616	655909
Genotypes	4	119.667**	46.767 **	393.43**	3.64179**	566707N.S
Error	8	0.117	0.9667	3.733	0.28411	425139
Total	14					

i. ** significant at 1% level of probability,

ii. N.S Non-significant at 5% level of probability.

Table 3 Mean performance of some quantitative traits of advance wheat genotypes ESW-9525 and NIA-10/8

Genotypes	Days to heading	Days to maturity	Plant height (cm)	1000- Grain weight	Grain yield kg ha ⁻¹
ESW-9525	75 B	126 A	108 B	38.3 C	3778 A
NIA-10/8	78 A	125 A	120 A	41.2 A	4167 A
MSH-3	66 D	119 B	98 C	40.7 AB	4694 A
MSH-5	68 C	119 B	96 C	40.0 B	4778 A
MSH-36	63 E	117 C	91 D	40.0 B	4695 A
LSD-value	0.6431	1.8512	3.638	1.0036	1227.7
Grand Mean	70	121.13	102.53	40.056	4422.3
CV	0.49	0.81	1.88	1.33	14.74

Table 4 Response of varieties/genotypes to leaf rust included in NWDSN during 2012-2013

Lines	Karachi	Tandojam	Sakrand	Thatta	Bhawalpur	Faisalabad	ACI
ESW-9525	20MS	TMS	TMS	5MSS	20MRMS	10MRMS	6.7
NIA-10/8	0	TMS	TMS	0	TMR	0	0.3
MSH-3	40MSS	20MSS	20MSS	10MSS	0	10MRMS	14.5
MSH-5	TMSS	TMS	TMS	5MSS	5MRMS	5MR	2
MSH-36	20MSS	10MS	10MS	5MSS	20MSS	40MRMS	12.8
Morocco	70 S	90 S	90 S	80 S	80S	70 S	80
Kiran-95	10MSS	10MSS	10MSS	40MSS	0	0	10.5
NIA-Amber	20MSS	5MSS	5MSS	10MSS	0	0	6

Table 5 Response of varieties/genotypes to stem rust included in NWDSN during 2012-2013

Lines	Karachi	Tandojam	Thatta	ACI
ESW-9525	0	0	0	0
NIA-10/8	TM	0	0	0.2
MSH-3	5MR	0	0	0.67
MSH-5	TMR	0	0	0.13
MSH-36	5M	0	20M	5
Morocco	80S	60 S	70 S	70 S
Kiran-95	40MSS	0	20MSS	18
NIA-Amber	40MS	0	40MSS	22.7

Table 6 varieties/genotypes resistant to yellow rust

S.No	Lines/Varieties	Islamabad	Nowshahra	Peshawar	ACIs.
1	ESW-9525	5MR	30RMR	20MR	6.3
2	NIA-10/8	0	10RMR	0	1
3	MSH-3	80s	80s	70s	76.6
4	MSH-5	60MRMS	30MRMS	20MRMS	22
5	MSH-36	60MRMS	60MRMS	40MRMS	32
12	Kiran-95	70s	70s	60s	66.7
13	Morocco	90s	100s	90s	93.3
14	NIA-Amber	10MRMS	40MRMS	0	10

Table 7 Genotypes/varieties with desirable/acceptable ACIs to Yellow, Leaf and Stem rusts during 2012-13

Lines	Yellow	Leaf	Stem
ESW-9525	6.3	6.7	0
NIA-10/8	1	0.3	0.2

Conclusion

Finally, results for the disease resistance with acceptable ACIs for rusts, two newly evolved advanced wheat genotypes (NIA-10/8 and ESW-9525) exhibited improved genetic traits for resistance against rust diseases (Table 7) and with improved yield potential produced 3778 and 4167 grain yield kg ha⁻¹ respectively. Genotype NIA-10/8 indicated the lowest ACIs value 1.0, 0.3 and 0.2 for yellow, leaf and stem rust diseases, respectively. However, ESW-9525 also showed lowest ACIs values (6.3, 6.7, and 0.0) for yellow, leaf and stem rust diseases, respectively. This study will be helpful for wheat breeders in creating rusts resistance in bread wheat. Genetic erosion of wheat demands diverse genetic resources to broaden the genetic base and attain diversification that ensures high through put resistance against biotic stresses including wheat rusts. The screened material will be incorporated further in hybridization programs to create genetic variability against rusts.^{29–32}

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Conflict of interest

The author declares no conflict of interest.

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