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Field-Based Assessment of Partial Resistance to Yellow Rust in Wheat Germplasm

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ABSTRACT

Durable resistance based on partial resistance is an important and effective way to combat the problem of yellow rust (Puccinia striiformis West. tritici). Field-based assessment of partial resistance is crucial in developing countries for the breeders, dealing with hundreds of lines at a time. The present experiment was carried out during 2005-2006 to reveal variability for field based-partial resistance to yellow rust among 20 wheat breeding lines grown at Nuclear Institute for Food and Agriculture, Peshawar, along with 'Morocco' as susceptible check. Partial resistance was assessed through the infection type, final rust severity (FRS), area under rust progress curve (AURPC), infection rate (IR) and co-efficient of infection (CI). Cluster analysis of the 20 wheat lines revealed two main groups/clusters along Morocco as a separate cluster. Based on overall parameters, these lines were grouped into two clusters. Nine lines were grouped in one cluster, while remaining 11 lines were clustered in another group. Similarly, cluster analysis based on partial resistance parameters also resulted in two groups for the tested lines along with Morocco as a separate line. The first cluster included the lines considered as moderately slow yellow rusting lines while those of later group were marked as better slow rusting lines. Strong association was found between co-efficient of infection (CI) with both FRS and AURPC, while it was too weaker with IR. The present study revealed that the lines were having enough diversity regarding slow rusting behavior and yellow rust resistance, ranging from immunity to partial resistant lines. Similarly, CI, FRS and AURPC are suggested to be useful for assessment of partial resistance to yellow rust.

Key words: Wheat, yellow rust, partial resistance, field-based assessment.

INTRODUCTION

Improvement of wheat (*Triticum aestivum* L.) is a major goal of plant breeders to ensure food security and self sufficiency. Severe losses due to different wheat diseases, including stripe rust have been reported (Kissana *et al.*, 2003). Among all the control measures of this disease, genetic resistance is the only economic and practical control measure, causing no additional cost to the farmer (Singh *et al*., 2004). However, only race-specific, major genes based resistant have been deployed in past. Furthermore, most of the released varieties were based on only a few major genes. This results in a kind of mono-culturing regarding resistance genes. Inqilab in Pakistan and PBW343, in India; both were based on Yr27 (Singh *et al.,* 2004), which has been broken down causing severe losses (Kisana, 2003). Such major gene(s)-based resistance are lost very rapidly due to evolution of virulence by the pathogen to these genes. The alternative is to search for partial

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resistance based on minor genes, which imparts durability (Singh *et al.,* 2004). This, in addition, will result in diversification of wheat genotypes in terms of their resistance background, necessary to avoid rapid evolution of the rust pathogen to acquire new virulence.

Field-based assessment of partial resistance is crucial in developing countries for the breeders, dealing with hundreds of lines at a time. Partial resistance could be assessed through different measures. This may be final rust severity (FRS) (Parlevliet, 1985), area under rust progress curve (ARUPC) (Wilcoxson *et al.,* 1975), infection rate (IR) (Broers *et al.,* 1996) and co-efficient of infection (CI) (Pathan and Park, 2006). Slow rusting, a mechanism of partial resistance has been assessed through AUDPC, infection rate and final disease severity by Ali *et al.* (2007). Thus the level of partial resistance in a given set of breeding lines may be assessed, in the form of slow rusting, which reduces the epidemic progress over the season, through AUDPC, FDS and infection rate (Broers *et al.,* 1996; Ali, 2007a). While on single scoring basis partial resistance, in general sense, may be determined through co-efficient of infection and average co-efficient of infection (Pathan and Park, 2006). Co-efficient of infection is the most commonly used parameter for assessment of yellow rust, used by different researchers (Shah *et al.,* 2003). Thus the association between co-efficient of infection and other partial resistance parameters were studied.

Previously different researchers (Mirza *et al.,* 2000) have evaluated different wheat lines for yellow rust resistance; however, their studies were based solely on vertical resistance. However, there is a need to search for diverse sources of breeding lines with partial resistance. Development of improved varieties based on partial resistance with diverse sources will help combat the rust problem. The present study was thus designed to assess diversity among wheat breeding lines for field-based partial resistance. The paper reports the preliminary assessment of wheat lines and their grouping based on their disease response in terms of partial resistance.

MATERIALS AND METHODS

Breeding material was obtained from Nuclear Institute for Agriculture (NIA) Tandojam, Sindh, Pakistan under a coordinated research program by Nuclear Institute for Food and Agriculture (NIFA), Peshawar. The liens were coded as NIA-1, NIA-2 etc. These were sown small adjacent plots of two rows plot^{-1}, with each row of 2.5 m length separated by 0.3 m with a distance of 0.6 m between entries at NIFA, Peshawar. Morocco, a super susceptible wheat cultivar, was sown around entries as spreader and also to serve as an adult plant susceptible check.

A high disease pressure was created through artificial inoculation with rust inoculum, obtained from Crop Diseases Research Program (CDRP) of National Agricultural Research Center (NARC), Islamabad. The inoculum was carrying virulence to yellow rust resistance genes Yr1, Yr6, Yr7, Yr8, Yr9, Yr17, Yr18 and Yr27. Yr urediniospores suspension was made in double distilled water (having 2-3 drops of non-phytotoxic wetting agent) with 300 mg of spores per liter of water. The inoculum was applied through turbo-air sprayer as fine mist, 2-3 times after the sun set as described by Roelfs *et al*. 1992.

Partial resistance behavior was assessed through host response and epidemiological parameters estimates *i.e.,* AURPC, FRS and Infection rate and CI. Disease Scoring was made four times at seven days interval, starting when Morocco reached 50% severity according to the Modified Cobb Scale (Paterson *et al.*, 1948). The Area under Rust Progress Curve (AURPC) was estimated following Pandey *et al*, (1989), FRS was computed as final severity in comparison with Morocco. Infection rate ‘r’, the unit leaf area damaged by disease per day was estimated for the whole epidemic period after the time when Morocco showed >50% severity, following Vanderplank (1968). Relative forms of these were worked out by comparing respective values of each entry with Morocco. CI value was calculated following Pathan and Park (2006).

Kernel weight was taken for 500 kernels, which was converted to 1000-kernel weight. Entire two rows of each entry were harvested and their grains were weighed through electronic balance to calculate grain yield. Diversity among these was estimated and grouping was made on the basis of cluster analysis of slow rusting epidemiological traits *i.e.,* AURPC, FRS and Infection rate, using computer package NTSYSpc.

RESULTS AND DISCUSSION

To assess variability among wheat breeding lines for durable resistance, parameters used as criteria to identify genotypes with partial resistance under field conditions included infection type, final rust severity, AURPC, infection rate and CI. Results regarding these parameters are described as under:

Partial resistance parameters

Data on parameters regarding partial resistance is shown in Table 1. A high disease pressure was observed as revealed from severity on susceptible check. Morocco exhibited S type of disease reaction. NIA-4, NIA, 18 and NIA-19 showed MR type of reaction. Fourteen lines having MRMS type of disease reaction while immune type of reaction was observed only for NIA-6 and NIA-14. Based on final rust severity we obtained three ranges *i.e.,* 0-30%, 31-70% and >70%. Only susceptible check was having >70% FRS value. Five entries among the tested lines (*i.e.* NIA-1, NIA-3, NIA-8, NIA-12 and NIA-17) were having maximum FRS 70% of the susceptible check. Four lines (NIA-4, NIA-5, NIA-15 and NIA-20) exhibited disease severity up to 30% of the susceptible check and were marked to be having better resistance. Thirteen lines displayed relative final disease severity up to 70% of susceptible check and were marked to be moderately resistant. FRS represents the cumulative result of all resistance factors during the progress of epidemic (Parlevliet and van Omeren, 1975). Previously, Herrera-Foessel *et al.* (2007) also used FSD as a parameter to assess slow rusting behavior of wheat breeding lines. They observed lower FRS value for durum lines exhibiting slow rusting, a kind of partial resistance, as compared to susceptible checks.

Table 1. Partial resistance parameters along with 1000-kernel weight and grain yield of NIA-wheat breeding lines at NIFA, Peshawar, during 2005-2006

Genotypes	Infection Type	Relative Disease severity	Relative AURPC value	Relative infection rate	CI value	1000-kernel weight (g)	Grain yield (kg)
NIA-1	MRMS	70	33	1350	52.5	42	1.2
NIA-2	MRMS	50	22	1300	37.5	42	0.6
NIA-3	MRMS	70	37	1350	52.5	44	0.8
NIA-4	MR	20	11	1100	10	43	0.6
NIA-5	MRMS	20	7	1100	15	42	0.8
NIA-6	I	0	0	0	0	42	0.6
NIA-7	MR	10	12	0	5	35	0.6
NIA-8	MRMS	70	57	200	52.5	39	0.6
NIA-9	MRMS	40	22	1250	30	39	0.6
NIA-10	MRMS	60	31	1350	45	47	0.8
NIA-11	MRMS	60	25	1350	45	49	1
NIA-12	MRMS	70	30	1350	52.5	50	0.8
NIA-13	MRMS	50	28	350	37.5	43	0.8
NIA-14	I	0	0	0	0	48	0.8
NIA-15	MRMS	30	32	250	22.5	43	0.8
NIA-16	MRMS	40	34	300	30	39	0.6
NIA-17	MRMS	70	52	250	52.5	44	0.6
NIA-18	MR	40	35	300	20	37	0.6
NIA-19	MR	40	45	50	20	40	0.6
NIA-20	MRMS	30	30	100	22.5	39	0.6
Morocco	S	100	100	100	100	36	0.56

Based on the AURPC values, breeding lines were categorized into two distinct groups *i.e*., those exhibiting relative AURPC values up to 30% of check and those showing AURPC values up to 70% of check. These lines exhibited moderately susceptible (MS) or susceptible (S) type of infection but the disease progress was lower over the season as compared to susceptible check. Breeding lines with such traits are expected to possess genes that confer partial resistance (Parlevliet, 1988). Ten breeding lines exhibited relative AURPC values less than 30% of Morocco and were marked to be having better level of partial resistance. Lines having relative AURPC values up to 70% of susceptible check were grouped as moderately resistant comprised of NIA-1,

NIA-3, NIA-8, NIA-15, NIA-16, NIA-17, NIA-18 and NIA-19. These all are considered to be having varying degrees of partial resistance which has been advocated to be more durable (Singh *et al*., 2004). Furthermore, lines with acceptable levels of partial resistance restrict the evolution of new virulent races of the pathogen because multiple point mutations are extremely rare in nature (Schafer and Roelfs, 1985). Previously, Broers *et al.* (1996) has also evaluated wheat lines for their slow rusting ability through AUDPC finding that resistance levels ranged from very low (in Taichung 23) to very high (in Parula) among the tested lines.

Relative infection rate (r) ranged from 0 to 1350. NIA-7 showed a constant disease severity, thus showing no increase per unit time with r value of 0. The infection rate assumed for susceptible check 'Morocco' as 100. Lines having 'r' value up to 100 were marked to have better level of partial resistance, which included two lines. Six lines exhibited 'r' value up to 350, marked as moderately resistant. Five lines were having maximum 'r' values (1350). Present study demonstrated that the apparent infection rate 'r' seemed to be an unreliable estimate of partial resistances when compared with disease severity and AURPC because it did not mark Morocco as the fast ruster. Moreover, more variation in r among the tested lines than the disease severity and AURPC, is partly because apparent infection rate is a regression coefficient with larger error variance. Similar results were found for stem rust and leaf rust of wheat (Ali *et al.,* 2007; Broers, 1989 and Rees *et al.,* 1979).

Data regarding CI value are given in Table 1. lines with ACI values of 0-20, 21–40 and 41–60 will be regarded as possessing better, moderate and low levels of partial resistance, respectively. NIA-4, NIA-5, NIA-7, NIA-18 and NIA-19 were having CI values up to 20 and were marked as possessing better level of partial resistance. NIA-2, NIA-9, NIA-13, NIA-15, NIA-16 and NIA-20 exhibited CI value up to 40 and were marked as moderately resistance. NIA-1, NIA-3, NIA-8, NIA-10, NIA-11, NIA-12 and NIA-17 showed CI value up to 60, marked as to have low level of partial resistance. Only susceptible check Morocco was having CI value of 100. Previously, Pathan and Park (2006) evaluated adult plant resistance (APR) to leaf rust, a kind of partial resistance, in European wheat lines and reported different levels of APR among the tested lines.

Susceptible check having maximum relative disease severity and relative AURPC value produced kernels with least kernel weight (36g) after NIA-7 (35g) and minimum grain yield. NIA-7 was having low 1000-kernel weight; despite of slow rusting behavior may be due to its lower genetic potential and not due to rust infection. Maximum grain yield per plot was produced by NIA-1 (1.2kg) followed by NIA-11 (1.0 kg), having relative AURPC values of 33% and 25%, respectively. Previously, Allan *et al.* (1963) have also reported impact of rust infection on grain yield losses.

Association between partial resistance parameters

Field-based assessment of partial yellow rust resistance was assessed through final rust severity, ARPC, infection rate and co-efficient of infection. Co-efficient of infection is the mostly used parameter for the purpose. During our study, an attempt was made to elucidate the association between these parameters. Positive relation of coefficient of infection was found with FRS and AURPC with a strong R^2 value *i.e*., 0.94 and 0.71, This relationship was positive, however, of the weaker nature with infection rate (R^2 = 0.06). This may be due to the fact that apparent infection rate is a regression co-efficient with larger error variance. Similarly, the data was initiated when the disease was already 50% on susceptible check. This also imparts an additional biaNIAess for infection rate of the check. However, on overall basis, CI could be used for field based assessment of partial resistance.

Diversity among Breeding Lines

Cluster analysis of the 20 wheat lines revealed two main groups/cluster along Morocco white as a separate cluster. Based on overall parameters, these lines were grouped into two clusters (Fig. 1). NIA-1, NIA-3, NIA-10, NIA-12, NIA-11, NIA-2, NIA-9, NIA-4 and NIA-5 were grouped in one cluster, while NIA-6, NIA-14, NIA-7, NIA-8, NIA-17, NIA-16, NIA-18, NIA-20, NIA-19, NIA-13 and NIA-15 were clustered in another group. NIA-16 and NIA-18 were found to be identical based on the five parameters.

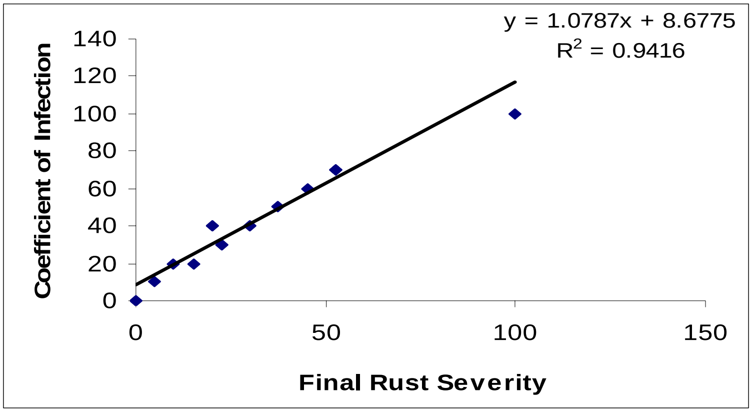

Fig. 1a. **Association between final rust severity and co-efficient of infection for assessment of partial resistance**

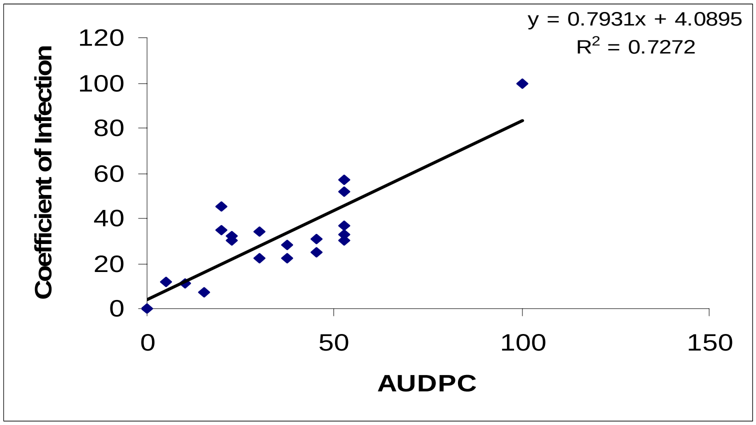

Fig. 1b. **Association between AURPC and co-efficient of infection for assessment of partial resistance**

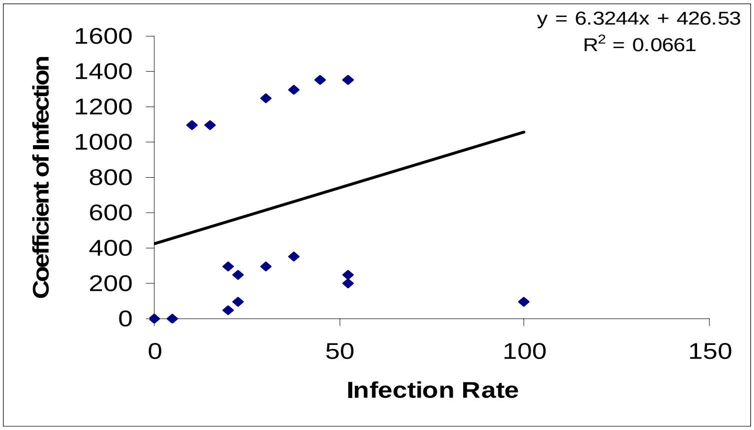

Fig. 1c. **Association between infection rate and co-efficient of infection for assessment of partial resistance**

Cluster analysis based on slow rusting parameters also resulted in two groups for the tested lines along with Morocco as a separate line. Here the pattern was a bit different (Fig. 2). NIA-1, NIA-3, NIA-10, NIA-11, NIA-2, NIA-9, NIA-4 and NIA-5 were grouped in one cluster, while NIA-6, NIA-14, NIA-7, NIA-8, NIA-17, NIA-13, NIA-15, NIA-20, NIA-16, NIA-18 and NIA-19 were grouped in another cluster. The first cluster comprises on the lines considered as moderately slow yellow rusting lines while those of later group were marked as better slow rusting lines. NIA-6 and NIA-14 were similar based on the three slow rusting parameters, because these two were found to be immune. These two lines could be inferred to carry major gene or combination of major genes based resistance, effective against all virulences used. These lines should be further subjected to inheritance studies or marker assisted identification for exploring basis of their resistance displayed in the current study. The present study reveals that the lines were having diversity regarding partial resistance, ranging from immunity to partial resistant lines. This diversity may be exploited in further breeding programmes.

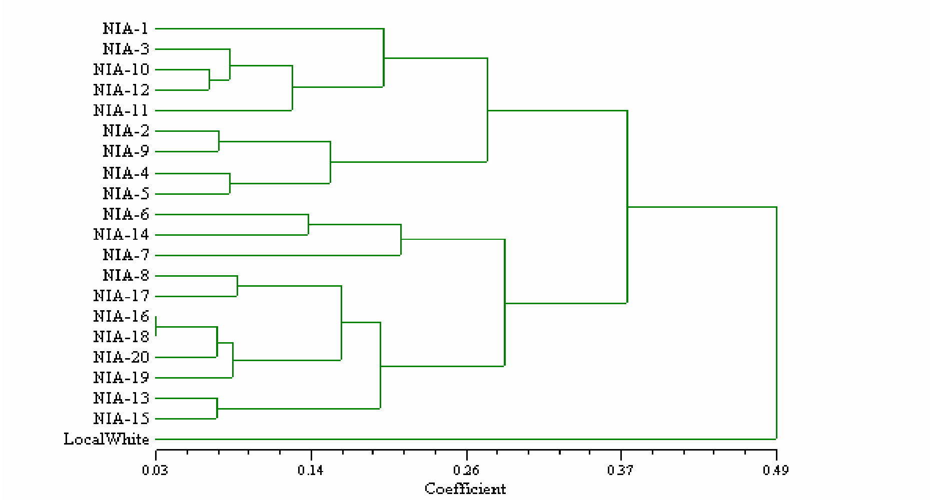

Fig. 2a. Dendrogram based on cluster analysis of the wheat breeding lines based on five traits, including disease resistance and yield traits

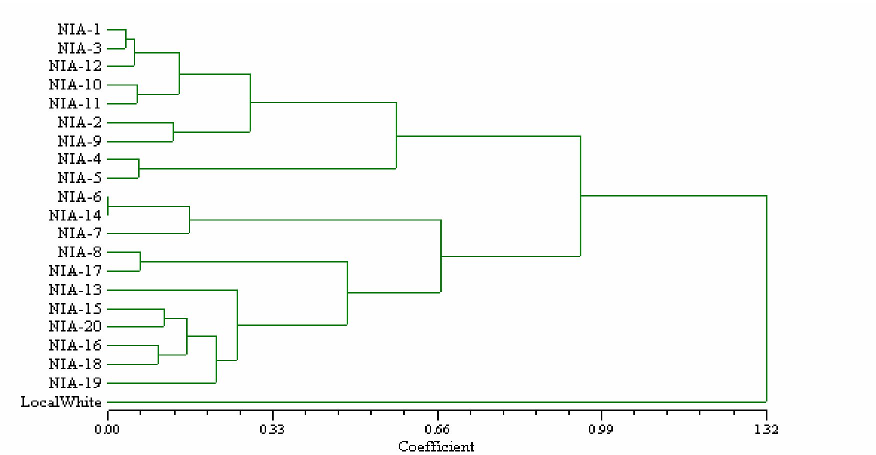

Fig. 2b. Dendrogram showing a cluster analysis of the 20 wheat breeding lines based on partial resistance

CONCLUSION AND RECOMMENDATIONS

The present study reveals that the lines were having enough diversity regarding partial resistance, ranging from immunity to partial resistant lines. Most of the tested lines exhibited better performance under high disease pressure shown by susceptible check. Resistance of all categories including immune to partial resistance to yellow rust were observed. These lines were supposed to be having genes for varying degrees of slow yellow rusting and enough diversity was observed to be used for further genetic manipulations. Further testing for stability over years and locations for yellow rust along with other desirable characters must be made before approval.

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