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Full Length Research Paper

Genetic studies in wheat for leaf rust resistance (*Puccinia recondita*)

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Leaf rust is a major disease of wheat crop in the world as a whole. This study was undertaken to find the genetic effects of adult plant leaf resistance in wheat (*Triticum aestivum L.*). Three wheat crosses were developed from three resistant and one susceptible parent. Six populations (P_1, P_2, F_1, F_2, BC_1 and BC_2) of each cross were grown under field conditions and were artificially inoculated with isolates of mixture of leaf rust prevalent races. Leaf rust intensity and reaction type were observed and the coefficient of infection was computed. Generation means and variance analyses were performed for the estimation of additive, dominance and epistatic genetic effects. Additive and dominance, as well as epistatic genetic effects, are involved in the inheritance of leaf rust resistance. However, the narrow sense heritability estimates were low, which also exhibited the presence of epistatic genetic effects. Thus, selection of resistant adult plant in later segregating generations would be useful for the development of high yielding wheat genotypes.

Key words: Wheat, leaf rust, *Puccinia recondite*, genetic studies, Pakistan.

INTRODUCTION

The disease leaf rust caused by *Puccinia recondita* f. sp. tritici has been reported to be a serious disease of wheat in the world (Sayre et al., 1998). Chemical control of the disease adds to the cost of production, whereas the development of resistant wheat varieties is effective in controlling the disease. Although some genes confer disease resistance to plant both at seedling and adult stages, wheat varieties with adult plant resistance to disease are however, considered more important than those of seedling resistance (Simons, 1975). The resistance can be regarded as oligogenic if the segregating population falls into clearly defined and easily recognizable categories by the reaction type, but the segregating population from parents differing in resistance often shows a continuous range of reaction type and disease intensity under field conditions. The knowledge about the nature and magnitude of genetic effects of the trait would greatly help wheat breeders in formulating an efficient breeding programme to tailor disease resistant wheat varieties.

The individual gene effects for disease resistance cannot be measured, in that the genes must be considered *en masse* and the statistical procedures may be used to obtain basic genetic information. However, several scientists have described the genetic models. Anderson and Kempthorne (1954), Cockerham (1954) and Hayman and Mather (1955) proposed the genetic models that permitted the estimation of additive, dominance and epistatic effects, whereas Robinson and Comstock (1955) observed that additive genetic variation is greater in those attributes with a less complex inheritance. Inclusively, Hayman (1958) described the estimation of the additive, dominance, additive x additive, additive x dominance and dominance x dominance gene effects. Nonetheless, the generation means analysis described by Mather and Jinks (1982) is relatively an easy technique to estimate the components of genetic

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Table 1. Details of the wheat material used in the studies.

Population	Cross-1	Cross-2	Cross-3
P_1	SA42	SA42	SA42
P_2	Inqilab91	MH97	Parula
F_1	SA42 xInqilab91	SA42x MH97	SA42 xParula
F_2	SA42 xInqilab91	SA42x MH97	SA42 xParula
BC_1	SA42 *2 x Inqilab91	SA42*2x MH97	SA42*2xParula
BC_2	SA42 x 2* Inqilab91	SA42 x 2*MH97	SA42 x 2*Parula

* = Backcross.

variance.

In this study, the procedure described by Mather and Jinks was used to determine the genetic effects of the leaf rust field resistance in wheat. The information would be useful for breeders to develop high yielding wheat varieties with increased field resistance to leaf rust.

MATERIALS AND METHODS

Development of materials and data collection

Three leaf rust resistant wheat varieties (Inqilab 91, MH97 and Parula) and one susceptible variety (SA42) were crossed to develop F_1, backcrosses and F_2 populations. The detail of the wheat material included in this study is given in Table 1.

The parents, F_1, F_2 and backcross generations were planted in the field during year 2000 to 2001 in a randomized complete block design with three replications in a separate experiment for each cross. Fundamentally, a single row that is 3 m long in length for each of the parents and F_1 generation, 4 rows for each of the backcrosses and 8 rows for the F_2 generation per replication was planted. Row to row and plant to plant distance were 30 and 15 cm, respectively. Spreader rows of the susceptible variety (Morocco) were planted around each replication to develop rust inoculum in the field. These spreader rows were artificially hypodermic and were inoculated with a mixture of pathogen of prevalent races for leaf rust at the beginning of the culms elongation stage of plant growth. Fresh inoculum was collected from spreader rows, while plots were inoculated by spraying and dusting. Consequently, the plots were irrigated frequently to facilitate the rust infection. Leaf rust data were recorded on 15 plants from each of the non-segregating generations, 50 plants from each of the backcrosses and 100 plants from the F_2 population selected randomly in each replication. On the appearance of leaf rust 100S on the susceptible parent, rust observations were recorded on individual plant basis, and the coefficient of infection (CI) was computed according to the modified Cobb scale method (Peterson et al., 1948). However, leaf rust severity was recorded as percentage and response was noted as infection type.

The field score (severity and field response) for the leaf rust was converted to a coefficient of infection (CI) by multiplying severity with the response constant value for field response as described by Stubbs et al. (1986) and Roelfs et al. (1992).

Statistical analysis

The data on the coefficient of infection were subjected to analysis of variance using the procedure described by Steel and Torrie (1980).

Generation means and variance analysis

Generation mean and variance analysis was performed using the computer programme (propounded by Dr. Tanwir Ahmad Malik, Associate Professor Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad, Pakistan) developed on the procedures described by Mather and Jinks (1982). Means and variances of parents, F_1, backcrosses and F_2 from individual plants pooled over replications were used in the analysis. The weighted least squares analysis was applied on the generation means commencing with the simplest model using parameter m only. Further models of increasing complexity (md, mdh, etc) were fitted, but the best-fitted model was picked up as the one, which had significant estimates of all parameters along with non-significant chi-square. The higher value for the parent was taken as P_1 in the model fitting.

Model fitting for weighted least square analysis of variance was started by using parameter E only, then parameters D, H and F were included until a satisfactory fit was achieved. The best model was chosen with significant parameters and non-significant chi-square.

Heritability estimates

Heritability in a narrow sense was calculated (Mather and Jinks, 1982) via components of variance from the best fit model of weighted least squares analysis using the following formula:

$$h2\ ns = 0.5\ D / 0.5D + H + E$$

RESULTS

The analysis of variance revealed high significant differences (P<01) in the generation's means in all crosses, indicating that a sufficient genetic variability existed in the material studied. Although, SA42 was used as the susceptible female parent in all the three crosses, the range in the coefficient of infection was 95 to 100% in the parent while it was 5.4 to 7.67 in F_1 and 28.58 to 31.13 in F_2. The range in coefficient of infection in the resistant parents (Inqilab91, MH97 and Parula) was 1.93 to 13.67.

Generation means analysis

In Table 2, the results of the generation means analysis

Table 2. Means and range in coefficient of infection (C1) in six generations of three wheat crosses.

Generation	SA42xInqilab.91		SA42xMH97		SA42xParula	
	Range	Mean	Range	Mean	Range	Mean
P_1	95 -100	99.5	95 -100	99.50	95 - 100	99.50
P_2	6 - 9	7.73	10 - 15	13.67	1.4 - 3	1.93
F_1	3 - 9	7.67	4 - 7	6.40	3 - 6	5.40
F_2	0 - 100	31.13	0 -100	28.58	0 - 100	29.53
BC_1	0.2- 100	25.53	0 - 100	24.98	0.2 - 100	32.0
BC_2	0 - 100	27.70	0 -100	18.1	0.2 - 100	19.52

were given, while in Table 3, the expression of genetic effects was variable in the three wheat crosses for leaf rust reaction. A four parameters model (m, d, h and j) provided a satisfactory fit for crosses SA42 x Inqilab-91 and SA4 x Parula while for cross SA42 x MH97, five parameters model (m, d, h, I and j) provided the best fit for the data; the magnitude of additive effects was high and similar in all the crosses. Also, the magnitude of dominance and interactions was high in the crosses, but they were relatively variable.

Generation variance analysis

In Table 4, the results of the generation variance were given. The model with D (additive), H (dominance) and E (environmental) components was fitted to explain the genetic variation of leaf rust in all the three crosses. The magnitude of additive effects was higher when compared to dominance and environmental effects, while the environmental effects were lower when compared to the genetic effects.

Heritability estimates

Narrow sense heritability estimates for leaf rust are given in Table 4, and it ranged from 13.5 to 21.15% in the crosses.

DISCUSSION

The knowledge about the nature and magnitude of genetic effects prevailing in the breeding material is required to decide what kind of selection procedure should be utilized in a breeding programme, due to the fact that crop improvement depends on the magnitude of genetic variability and the extent to which the desirable character are heritable. The estimation of the knowledge of heritability also helps in predicting the behaviour of the succeeding generations and the appropriate selection procedure adapted. If heritability is higher, the selection process may be simple and greater response to selection may be expected in the succeeding generations.

In the inheritance of leaf rust resistance in all the types of gene effects, additive, dominance and interaction prevailed in the genetic variation in all the crosses. However, additive and additive x dominance interaction were of the same magnitude in all the crosses while additive and additive interaction was only expressed in cross SA42 x MH97; additive x dominance interaction prevailed in all the crosses. So, additive x dominance interaction appears to be relatively more responsible for leaf rust reaction (Senapathi et al., 1994). The presence of both additive and non-additive gene effects has also been reported for the yellow rust of wheat by Krupinsky and Sharp (1978). Bjarko and Line (1988) have reported predominance of additive gene action for slow rusting resistance to leaf rust in wheat, while Skovmand et al. (1978) reported same predominance for slow rusting resistance to stem rust resistance in wheat. The presence of interactions in controlling leaf rust resistance suggest that selection of resistant plant would be meaningful only in a later segregating generation (Yadav et al., 1999).

Dominance effects were negative in all the three crosses. The negative value of dominance suggested that alleles responsible for the decreased leaf rust incidence were dominant over the alleles causing leaf rust (Maarten and Scharen, 1987; Pawar et al., 1988). Classification of epistasis largely depends on the signs of (h) and (l). Similar signs of the two parameters, h and I, indicate predominance of the complementary epistasis (Singh and Singh, 1978).

The generation means analysis revealed the presence of gene interactions, while lower estimates of heritability also show the interaction of genes for leaf rust resistance. However, the generation variance analysis showed the absence of gene interaction. This discrepancy might be due to the difference in the estimation of the two analyses' precision. The analysis of the generation means was more robust when compared to the generation variance.

Conclusions

The results of all the crosses showed that additive, dominance and interactions were involved in the expression of

Table 3. Estimates of the best fit model in generation means analysis for leaf rust (CI) in three crosses of wheat.

S\N	Cross	Genetic effect					X^2	df	Probability
		m	D	h	i	J			
1	SA42 x Inqilab.91	51.72±4.11**	44.26±4.43**	-44.59±5.43**	---	-50.08±8.86**	0.367^{ns}	2	0.08325
2	SA42 x MH97	31.45±8.91**	43.44±5.19**	-24.89±9.34**	25.86±15**	-46.86±9.02**	0.20^{ns}	1	0.0656
3	SA42 x Parula	48.95±3.94**	47.09±4.04**	-43.93±4.97**	--	-44.94±8.75**	3.93^{ns}	2	0.1404

ns = not significant.

Table 4. Variance components D (additive), H (dominance) and E (environmental) in the analysis of variance and $h^2_{n.s}$ (heritability narrow sense) for leaf rust in three crosses.

Cross	Variance component				Probability	$h^2_{n.s}$
	D	H	E	X^2 (3df)		
SA42x Inqilab91	-976.20±310.84**	4101.08±541.52**	2.63±0.55**	1.00	0.8008	0.1350
SA42 x MH97	-1867.2±313.95**	5345.24±584.62**	2.29±0.48**	0.41	0.9384	0.2115
SA42 x Parula	-1628.6±314.06**	5034.33±575.43**	0.92±0.19**	2.24	0.5233	0.1930

genes for leaf rust resistance in wheat. Lower estimates of narrow sense heritability also indicated the presence of gene interactions. The presence of gene interaction suggests that breeding for leaf rust resistance in wheat and selection of resistant plants should be made in a later segregating generation. However, the varieties, Inqilab91, MH97 and Parula, would be exploited as a source of leaf rust resistance.

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