Estimation of gene effects and combining ability of latent period of stripe rust in advanced lines of wheat

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Abstract

Four advanced breeding lines of wheat which had appeared to be resistant to stripe rust in the past years along with a susceptible variety, Bolani, were intercrossed in all combinations of a half-diallel design. Seedlings were grown in greenhouse until the first leaves fully expanded and then inoculated with two pathotypes (races) $6E134A^+$ and $134E148A^+$, separately. Days to the first pustule eruption was recorded as latent period. Diallel analysis was performed by two methods of Griffing, and Jinks and Hayman. M-78-1 and M-78-10 were known as the best general combiners for longer latent period. Results of the analysis of variance of Wr+Vr and Wr-Vr, *Wr/Vr* regression analysis and estimates of genetic parameters indicated the importance of both additive and non-additive gene effects. Broad-sense heritability was 98% for both pathotypes. Narrow-sense heritability was 65% and 80% for $6E134A^+$ and $134E148A^+$ pathotypes, respectively.

Key words: Stripe rust, wheat, resistance, latent period

Introduction

Stripe rust, caused by *Puccinia striiformis* Westend., is a serious disease of wheat worldwide which causes major yield losses (Beard *et al.*, 2007). Developing resistant varieties is the most effective approach to control the disease. Seventy resistance genes have been reported, designated *Yr* (Dedryver *et al.,* 2009; Chen, 2005; McIntosh *et al.*, 2008). Two types of resistance have been distinguished; race-specific resistance and non race-specific resistance. Race-specific resistance is under monogenic control and can be overcome by genetic adaptation of the fungus and evolution of new virulent races. This type of resistance usually can be detected at the seedling stage, named as seedling resistance (SR), but is also expressed at all stages of plant growth. Non race-specific resistance is under polygenic control, quantitatively inherited and assumed to be durable (Johnson, 1984). This type of resistance, known as adult plant resistance (APR), is characterized by a susceptible infection type in the seedling stage and a slow epidemic development as adult plant stage (Broers *et al.*, 1997). The studies to characterize quantitative resistance to wheat stripe rust are limited (Mallard *et al.*, 2005). The latent period is one of the most important components of quantitative resistance (Parlevliet, 1975; Ghannadha *et al.*, 1995). It is measured and analyzed easily and with the least error (Ghannadha *et al.*, 2005; Shaner, 1980; Shaner and Finney, 1980; Kuhn *et al.,* 1978; Shaner *et al.,* 1978). This research was aimed to estimate genetic parameters and determine gene effects related to latent period.

Materials and Methods

Four advanced breeding lines of wheat which had appeared to be resistant to stripe rust in past years, M-78-1, M-78-3, M-78-10 and M-78-16, along with the susceptible cultivar Bolani were intercrossed in all combinations of a half-diallel design. The parents and F_1 progenies were planted in 10-cm pots in two separate randomized complete block designs, one for each pathotype, with three replications in the greenhouse. Inoculations were carried out by two pathotypes of stripe rust, 6E130A$^+$ and 166E42A$^+$, when the first leaf was fully expanded and the second leaf was about half the length of the first. For this purpose, all pots were sprayed by distilled water with one drop of Tween 20 per litre. The seedlings were then inoculated with a 1:4 ratio of spore and talk powder. The pots were left in a darkened moist chamber for 24h at 10±1°C and then moved back to the greenhouse and kept at at 15 ± 2°C. Days from inoculation to the first pustule eruption was recorded as the latent period. Data analysis was performed by both the graphical technique of Mather and Jinks (1982) and the combining ability method 2, model I (fixed effects) of Griffing (1956).

Results

The Results of ANOVA (Table 1) revealed significant differences among genotypes, for both pathotypes indicating the presence of genetic difference for the latent period in the studied lines. For both pathotypes line M-78-1 had the longest and susceptible cultivar, Bolani, had the shortest latent period. The mean squares for GCA and SCA are presented in Table 2. Both GCA and SCA were highly significant for both pathotypes. The ratio, 2 $MS_{GCA}/(2\ MS_{GCA} + MS_{SCA})$, was 0.85 and 0.92 for pathotypes 6E134A$^+$ and 134E148A, indicating the relative importance of additive to non-additive effects$^+$, respectively. GCA estimates for M-78-1 and M-78-10 lines were positive for both pathotypes, suggesting they are suitable parents for obtaining a longer latent period; whereas those for M-78-3, M-78-16 and Bolani were negative (Table 3).

Table 1. Duncan's multiple range test of wheat advanced lines and their progenies for latent period in response to two pathotypes of stripe rust.

Line/Cross	Pathotype	
	6E134A$^+$	**134E148 A$^+$**
Bolani	8.89 h	8.56 h
*M1×Bolani	10.11 gh	9.56 fgh
M3×Bolani	9.44 gh	8.67 gh
M10×Bolani	9.87 gh	10.22 efg
M16×Bolani	10.78 fg	10.22 efg
M1	20 a	17.56 a
M1×M3	11.89 ef	16.89 a
M1×M10	17.44 b	17.11 a
M1×M16	12.78 de	14.67 b
M3	14 cd	14.67 b
M3×M10	14.56 c	12.11 cd
M3×M16	12 ef	10.87 def
M10	14.56 c	16.33 a
M10×M16	11.78 ef	12.33 cd
M16	14 cd	13.22 b

Means followed by similar letters in each column are not significantly different (at 5% level).
*M1=M-78-1, M3= M-78-3, M10= M-78-10, M16= M-78-16.

Table 2. Analysis of variance for general and specific combining ability of latent period in response to two pathotypes of stripe rust

S.O.V.	df	Mean Square	
		6E134A+	**134E148+**
Repeat	2	2.63^{ns}	0.28^{ns}
GCA	4	27.78**	50.23**
SCA	5	9.78**	8.74**
Error	18	0.76	0.85
2*GCA*		0.85	0.92

** Significant at the confidence level of 1%.

Table 3. Estimates of general (on diagonal) and specific (above diagonal) combining ability of the latent period in response to two pathotypes of stripe rust.

	M1	M3	M10	M16	Bolani
6E134A+					
M1	1.33 *	-1.39*	2.28**	−0.32 ns	−0.57 ns
M3		-0.11ns	0.83 ns	0.35 ns	0.20 ns
M10			1.78**	-1.76**	-1.35 *
M16				-3.0**	*1.72
Bolani					-2.7
	SE(GCA)= 0.54			SE(SCA)= 0.67	
134E148A+					
M1	3.07**	1.76*	0.87 ns	−0.32 ns	-2.31**
M3		−0.19 ns	−0.87 ns	−0.95 ns	0.06 ns
M10			0.92 ns	0.50 ns	0.50 ns
M16				−0.34 ns	1.76*
Bolani					−3.45**
	SE(GCA)= 0.51			SE(SCA)= 0.81	

M1=M-78-1 M3= M-78-3 M10= M-78-10 M16= M-78-16

The combination of M-78-10×M-78-1 had the highest SCA effect for longer latent of 6E134A+ pathotype and the combinations M-78-3×M-78-1 and Bolani×M16 had those of 134E148A+ pathotype, suggesting the presence of non-additive gene action for the longer latent period in the relating hybrids. Both genetic parameters of *Wr+Vr* and *Wr-Vr* were significant for both pathotypes, indicating non-allelic interaction (Table 4). The coefficient of *Wr/Vr* regression (Table 5) had significant differences from zero while it was not significantly different with unit for both pathotypes, suggesting the presence of dominance and absence of non-allelic interactions. The coefficient of determination of *Wr/Vr* regression for pathotype 134E148A+ (0.93) was higher than that for 6E134A+ (0.46). The intercept of the *Wr/Vr* regression for both pathotypes was above origin indicating partial dominance (Fig. 1). Diallel statistics are presented in Table 6. Additive genetic variance (D) was greater than dominance genetic variances (H1 and H2) for both pathotypes.

Table 4. Analysis of variance of Wr+Vr and Wr-Vr for latent period in response to two pathotypes of stripe rust.

Source of variation	**Df**	**Wr+Vr (Mean square)**		**Wr-Vr (Mean square)**	
		6E134A$^+$	**134E148A$^+$**	**6E134A$^+$**	**134E148A$^+$**
Parents	4	429.3**	212.4**	11.37*	5.30**
Repeat	2	1.54 ^{ns}	82.4*	0.97 ^{ns}	1.73 ^{ns}
Error	8	12.5	16.6	2.22	0.45

* and ** Significant at confidence level of 5% and 1%, respectively.

Table 5. Confidence intervals for the regression coefficient of Vr (Variance of the progeny of each parent) and Wr (the covarinace of the progeny of each parent with non-common parents) for latent period of advanced lines of wheat.

parameter	**6E134A$^+$**	**134E148$^+$**
b	0.81±0.12**	0.79±0.13**
1-b	0.19±0.12^{ns}	0.21±0.13^{ns}

* and ** Significant at 5% and 1% levels repectively ^{ns} Non-Significant

F parameter had positive sign for 6E134A$^+$ and negative sign for 134E148A$^+$.Average degree of dominance was near to unit for both pathotypes. $H2/4H1$ was nearly 0.25 for both pathotypes indicating an equal frequency of increasing and decreasing alleles of the latent period for both pathotypes. K_D/K_R was larger than unit for 6E134A$^+$, indicating higher frequency of dominance alleles than that of recessive alleles, while for 134E148A$^+$ a reverse situation was observed.

Broad-sense heritability was high for both pathotypes, indicating low influence of environment on the latent period. The correlations between $Wr+Vr$ and common parent means were positive which indicated that increasing latent period was accompanied by increasing the value of $Wr+Vr$ which resulting from larger number of recessive alleles. In other words, the direction of dominance was toward decreasing the latent period. Regression graph of $Wr+Vr$ and common parent (Fig. 2) shows that Bolani had the shortest latent period and the least amount of $Wr+Vr$ for both pathotypes indicating the presence of dominant alleles for decreasing the latent period. Based on the *Wr/Vr* graph (Fig. 1) for pathotype 6E134A$^+$, M-78-1 line contained the most recessive alleles, while Bolani and M-78-16 contained the most dominant alleles and M-78-10 and M-78-3 were intermediate. Analysis of *Wr/Vr* graph for pathotype 134E148A$^+$ showed that M-78-1, M-78-3 and M-78-10 lines possessed the most recessive alleles, while Bolani had the most dominant alleles.

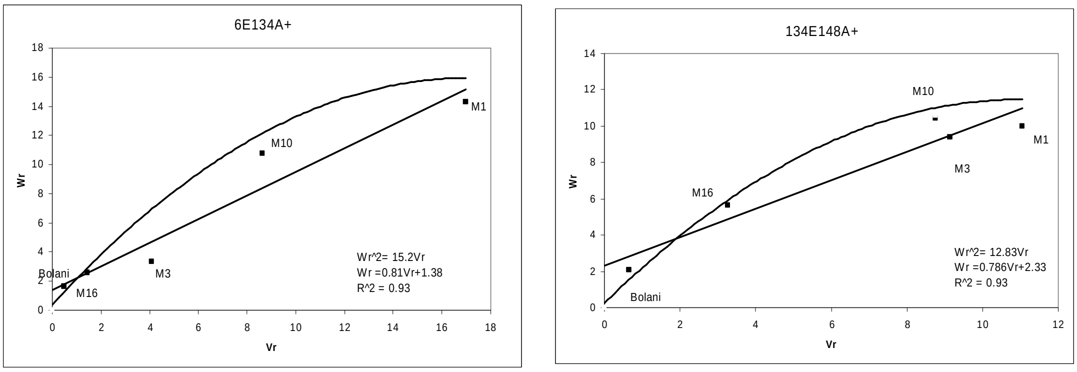

Fig. 1. Regression between Vr (Variance of the progeny of each parent) and Wr (the covarinace of the progeny of each parent with non-common parents) for the latent period of advanced lines of wheat in response to two stripe rust pathotypes.

M1=M-78-1, M3= M-78-3, M10= M-78-10, M16= M-78-16.

Table 6. Genetic statistic for the latent period of stripe rust in advanced lines of wheat.

parameter	6E134A$^+$	134E148$^+$
$D \pm SE(D)$	15.27±1.80	12.83±1.77
$H1 \pm SE(H1)$	14.15±1.89	8.73±1.52
$H2 \pm SE(H2)$	12.49±1.60	7.88±1.33
$F \pm SE(F)$	4.64±1.75	-4.14±1.28
$\sqrt{H1/D}$	0.96±0.08	0.83±0.1
$H2/4H1 \quad (UV)$	0.22	0.23
$KD/KR \quad (U/V)$	1.37	0.67
h^2b	0.98±0.01	0.98±0.01
h^2n	0.65±0.03	0.80±0.03
r(Pr,Wr+Vr,)	0.87	0.81

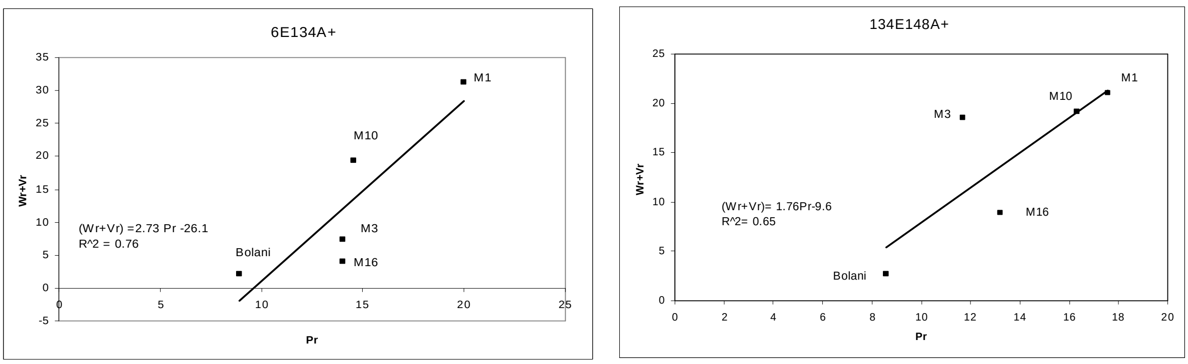

Fig. 2. Regression between Wr+Vr and mean of parents for latent period of advanced lines of wheat in response to two pathotypes of stripe rust.

M1=M-78-1, M3= M-78-3, M10= M-78-10, M16= M-78-16.

Discussion

Knowledge about the mode of genetic control on the desirable traits and the influence of environmental factors and interactions of genetic and environmental factors are essential to design and perform an effective and useful breeding program. Methods of diallel analysis suggested by Griffing (1956), Jinks (1954) and Hayman (1954) provides comprehensive information about breeding values and genetic potential of parents for use in breeding programs and about genetic superiority of progenies. Selecting suitable parents is important in success of a breeding program and could save time and energy in later stages. In this research, advanced lines of M-78-1 and M-78-10 were recognized as the best general combiners for the longer latent period of both pathotypes. Therefore, they are able to transfer their desirable trait (longer latent period) to the progenies easily. There was a disagreement between the analysis of variance of *Wr+Vr* and *Wr-Vr* and the result of the significance test for the departure of the regression slope from unity. It can be concluded that epistasis and/or correlated gene distribution was present. Lack of agreement between the analysis of variance of *Wr+Vr* and *Wr-Vr* and the result of the significance test for the regression slope was also reported by other workers (Ghannadha *et al.*, 1995). Presence of non-additive effects could be assigned to genetic complex of the trait due to a large number of controlling genes. In this case, selection in early generations would be of low efficiency. Besides, since the dominant alleles possessed shortening effect on the latent period, selecting progenies with longer latent period should be performed in later generations of segregating populations. High broad-sense heritability of latent period of both pathotypes suggests that direct selection for longer latent period could be successful and lead to high genetic gain. The large difference between broad-sense and narrow-sense heritabilities for $6E134A^{+}$ and low difference of those estimates for $134E148A^{+}$ suggests the importance of non-additive gene effects and importance of additive gene effects for the corresponding pathotypes, respectively. In overall, results of this research indicates the importance of both additive and non-additive gene effects in controlling the latent period of stripe rust in wheat.

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