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Gene Effects and Combining Ability in Some Bread Wheat Genotypes to Yellow Rust Disease

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Abstract: Ten wheat lines were studied to determine gene effects and combining ability in some bread wheat genotypes to yellow rust disease. Ten parental lines and F_1 were evaluated in a randomized complete block design with three replications in Agricultural and Natural Resources Research Center, Mashhad, Iran. Two races ($134E134A^+$ and $4E0A^+$) were used for this study. Latent Period (LP) and Infection Type (IT) were measured in the field and greenhouse. Results showed significant differences between races in their pathogenicity and between genotypes in their resistance to the pathogen. Diallel cross carried out between the parents and progenies and thereafter were analyzed by the method of Griffing and Haymans. The General Combining Ability (GCA) and Special Combining Ability (SCA) for all traits were significant and showed additive variance was more important. Test for validity of diallel hypothesis proved epistasis effect for all traits. P_1, P_2 and F_1 showed significant difference between all traits in generations mean analysis. Average degree of dominance ranged from partial to over dominance for resistance or susceptibility. Dominance, additive and epistatic types of gene action were responsible for the genetic control of the traits. However, except for additive-additive component, non-additive effect of genes could not be fixed by self-fertilization.

Key words: Latent period, infection type, additive genes, diallel analysis

INTRODUCTION

Wheat (*Triticum aestivum* L.) has the wide and high adaptability rate to different kinds of climates among the cereals. It is growing well in cold seasons. Genetic characters of quantities and qualitative traits and their heritability in wheat is the most important necessity to breed high yield varieties with high resistance to diseases. Wheat is exposed to different kinds of abiotic stresses (such as drought and cold stress) and biotic stresses (such as diseases and pest) making the wheat production through genetic improvements harder than before.

Nowadays yellow rust or strip rust is one of the well known diseases of wheat world-wide. This disease is caused by a fungus known as *Puccini striiformis* f.sp. *tritici* (Stubbs, 1988).

Wheat yellow rust is one of the most recognized diseases in Iran. Damage of this disease in Iran in season 1992-1993 was estimated about 1.5 million tons, which is about 15% up to 30% of total wheat production in Iran (Torabi, 2002). The yield increased by applying fungicide (Tsomin *et al*., 1990), but environmental pollution, cost of control convinced researchers decide to find a genetic control for production of resistant variety with different genotypes (Dehgani *et al*., 2005). Knowledge about the genetic resources is useful for breeding and helps to produce new lines. Wheat varieties with permanent specialized resistance to yellow rust are hard to reach and if reach, it will break down fast (Ahoumanesh, 2000).

Researchers are trying to produce varieties with slow rusting (Wiese, 2005). In the varieties with slow rusting, latent period is longer, infection and amount of spore production are lower and size of pustule on the plants are smaller (Tsomin *et al*., 1990). Falat is one of broken down resistance variety in Iran which has specialized genes Yr7 and Yr9. There was no virulence for Yr7 gene in Iran in the past years. Yr9 gene was only resistance gene in this variety from time of introduction until 1992 (when yellow

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rust was wide-spread in Iran). Because the resistance was observed in seedling stage, resistance easily broken down and caused epidemic (Afshari, 2006).

Genetic analysis of resistance components (kind of varieties and lines, type of infection, percentage of infection, acceptability, mean of infection index and latent period) were used to determine the number of resistant gene in varieties are important for production of resistant varieties (Afshari, 2006).

One of resistance component is infection type traits. Infection type is the result of interaction between pathogen and host. It is influenced by stage of growth in the time of evaluation between varieties, the amount of dosage applied for inoculation, interplot interference and presence of specialized gene (Gannadha *et al*., 1995). Infection type can be measured in the seedling stage or adult plant in greenhouse or field. Resistant varieties show less symptoms of disease.

Stubbs (1985) reported that F_1 and F_2 generations in the seedling stage produced by crossing three resistant wheat lines and one sensitive line to yellow rust, showed low infection type (higher resistant) controlled by recessive gene.

Latent period is also one of the key resistance components is defined as the number of days from the time of plant inoculation (first infection) until the time of appearance of secondary infection materials. Stage of growth and age of leaves play an important role to produce diversity in traits. The longest latent period is happening in the filament leaf and decreases from the upper leaves to the lower leaves (Gannadha *et al*., 1995). Younger and older plants have shorter latent period than others. The shortest latent period is happening in the seedling stage (Shaner, 1980; Shaner and Finney, 1980).

Selection of genotypes for longer latent period for those areas that spreading period of yellow rust is short, can be very important to lower the chance of epidemic (Parlevliet, 1977). Observed genetic variation in this two traits helps to achieve the control of gene function and contribution of each genetic variance component in controlling traits and reach special combining ability and general combing ability.

So far, many researches keen to determine the heritability of resistance component in the field. Chen and Line (1995a, b) in a complete 4×4 diallel with parents and F_1, F_2, BC_1 and BC_2 generations estimated broad sense heritability of about 95% and narrow sense heritability of about 86-95%.

Parlevliet (1977) reported the variance of special combining ability is 3 times more than variance of general combining ability for the resistance to yellow rust. Dehghani and his colleagues (2005) by using the mean generation analysis for evaluation of resistance to yellow rust were observed the dominance retrocession phenomena in two diallel back cross with Byplot method for two different yellow rust races. They also reported average percent of general combining ability and special combining ability were 69 and 48%, respectively.

Significant combining ability and maternal effect were observed in a 6×6 and 7×7 diallel experiments on parental plants of F_1 (Krupinsky and Sharp, 1978). Gannadha *et al*. (1995) in a 5×5 diallel in seedling stage find out that one up to three genes controlling the latent period traits. Dominance were observed in those with longer latent period.

In this study, the genetic resistances to yellow rust of wheat with data of two races, infection types and latent period traits caused by diallel cross have been studied.

MATERIALS AND METHODS

Ten bread wheat genotypes (Table 1) in a one-way diallel cross design were studied in a greenhouse and field study in Agricultural and Natural Resources Research Center, Mashhad, Iran in 2005. Two pathotype of yellow rust from Mashhad and Karaj were collected, purified and named Karaj ($134E134A^+$) and Mashhad ($4E0A^+$) according to the standard varieties in Johnson *et al*. (2000) method. Karaj race ($134E134A^+$) for plant with genes YrA, Yrcle, Yr9, Yr7, Yr6, Yr2 has virulence and were used to make an artificial inoculation of seedlings (Johnson *et al*., 2000).

Each cross line in two different crossing blocks was cultivated in the field. The methods of emasculation and pollination were commonly used method. Backcross lines (BC_1 and BC_2) were generated by backcrossing F_1 with the two parental lines. In order to evaluate in the field under mist system all the parental and progeny lines were cultivated in a randomized completely block design with three replications. Plot size was 100×40 cm. In a greenhouse five seeds of each parental progeny and progeny of backcrosses were cultivated in a pot with 15 cm diameters. Plants were inoculated when the first leaf was open. The spores were kept in −70°C. To germinate

Table 1: Lines and cultivars used in present study

Entry	Pedigree/name
1	Cook (Timgalen/condor sib.//condor)
2	Jupateco"73R"
3	YR18/6*Avocet"S"(ww119/ww15//Egret)
4	IQ7 = PBW343*2/Kukuna
5	Falat (Kvz/Buho"s://Kal/Bb = Seri82)
6	IQ10 = PBW343*2/kouk
7	IQ16 = Ingalab91*2/Tukura
8	Ghods(Rsh/5/Wt/4/Nor10/k54*2//Fn/3/Ptr/6/Omid//Kal/Bb)
9	Gascojen
10	Bolani (susceptible control)

spores samples were kept for four minutes in 42°C. Before spreading the spores, Tween 20 oil plus water with 1/1000 ratio was applied on the leaf surface to facilitate the spore germination. Spores with the 1/4 ratio were mixed by Talk powder. The inoculated plants were covered by black plastic and kept in 10°C and 100% humidity for 24 h. By then the pot moved to controlled conditions (temperature = 15±3°C, humidity = 70%).

To determine the infection type, reaction of parental plants 17 days after inoculation was registered. Parental plants with high resistance to infection type showed zero or close to zero infection. Parental plants with no resistance to infection type showed clorotic, stripe spot and spore germination. According to Johnson method, sensitive parental plants were located in infection types 7, 8, 9. Reaction of a genotype to pathotype agent of yellow rust depends on genetic characteristics of the genotype. In this study, appearance of pustule on the sensitive cultivars were recorded as latent infection period from time of inoculation until appearance of first pustule. 7 days after inoculation, all the pots were checked early morning to record the appearance of first pustule on the leaves. Plants were marked by a colored string fastened around them.

Two methods were used for diallel analysis; Hayman (1960) diallel method and Griffing (1956) method. The methods of Griffing (method 1, model 1) and Hayman are statistically similar in their analysis of variance. In other words the griffing's general combining ability component is mathematically identical to the Hayman's additive component. Griffing employs one specific combining ability and one reciprocal effect component. The diallel analysis studies developed by Hayman (1960), provides a fairly reliable mechanism to properly understand the nature of gene action involved in the development of complex genetic characters. Griffing (1956) first method consists of parents, F_1's and reciprocal F_1's. Diallel method is based on some hypothesis:

- Parents or lines should be pure and homozygote (such as line, clones and genetic materials)
- Parents or lines must have a heredity diploid system (like wheat)
- It is suitable that there was no parental interactions because in this situation, the genetic effects can be studied better. Each gene has two alleles and is independently distributed in parents

RESULTS AND DISCUSSION

Result show that latent period and infection type for both Karaj (134E134A$^+$) and Mashhad (4E0A$^+$) races had significant differences in resistance of genotypes (Table 2, 3). However, the differences in intensity of action, differences in reaction of varieties to different race traits and resistance components were observed. Therefore the diallel analysis was done for both traits. Each heredity resistance components were separately studied. Latent period is one of the most simple resistance components in variety measurements and has the lowest error. Coefficient of variation of traits for both races Karaj (134E134A$^+$) and Mashhad (4E0A$^+$) were 19.66 and 9.66, respectively. Latent period was widely dependent on spread of disease in the field (Table 2, 3).

Table 2: Analysis of variance of randomize completely block design to race of Karaj (134E134A$^+$)

		Means of square	
SOV	df	Infection type	Latent period
Replication	2	0.890	0.610
Genotype	54	9.880**	15.810**
Error	108	0.496	1.002
CV	-	19.570	19.660

**Significant at 1% level

Table 3: Analysis of variance of randomized completely block design to race of Mashhad (4E0A$^+$)

		Means of square	
SOV	df	Infection type	Latent period
Replication	2	8.32	1.491
Genotype	54	7.680**	15.193**
Error	108	0.64	0.917
CV	-	11.65	9.690

**Significant at 1% level

Latent period is also under control of other factors such as plant age and environmental factors. Latent periods become longer when plants age are increased. The longest time was in filament leaf stage (Dehghani, 2004). Decreasing of temperature increases latent period (Saidi *et al*., 1998). Singh *et al*. (1996) reported the latent period beside the genotype were under control of plant growth stage. In same environmental conditions, the latent period was under control of resistance and sensitivity of host, therefore the resistant varieties can be easily selected. Dehghani *et al*. (2002) expressed those genotypes had long latent period in seedling stage showing resistance and immunity on developmental stages.

Generally, the resistant parental plants have longer latent period than the sensitive one. The results of the present research also showed sensitive variety had lower latent period than resistant variety. Bolani, the control variety, was the first variety showing the disease symptoms. Resistant component for both races are shown in Table 4 referring the pathogenicity of the races. Two different races of rust showed remarkable correlation with each other. In addition, this correlation showed the length of latent period has significant linkage with infections type (Mashhad −0.75 and Karaj −0.85).

Table 4: Correlation coefficients of latent period and infection type traits

	Infection type trait	
	Mashhad race ($4E0A^{+}$)	Karaj race ($134E134A^{+}$)
Latent period	-0.75**	-0.85**

**Significant at 1% level

Table 5: Estimated parameters for latent period and infection type traits

	Karaj race ($134E134A^{+}$)		Mashhad race ($4E0A^{+}$)	
Genetic parameters	Infection type trait	Latent period	Infection type trait	Latent period
β-1	0.81±0.21	0.68±0.16	0.76±0.09	0.71±0.60
D±SE(D)	50.61±0.46	1.51±0.46	6.53±0.65	1.54±1.25
H_1±SE(H_1)	8.46±1.019	2.48±0.54	6.46±1.17	3.40±0.64
SE(H_2)±H_2	5.65±0.68	1.89±0.54	4.66±0.58	2.86±0.54
F±SE(F)	2.56±0.68	-0.91±0.23	-1.50±0.64	1.23±0.78
H1/D √	1.23	1.28	0.99	1.53
H2/4H1 √	0.17	0.44	0.42	0.46
Kd/Kd+Kr	0.54	0.43	0.43	0.49
$h^2_{b.s}$	97.0%	96.0%	98.0%	89.0%
$h^2_{n.s}$	56.0%	93.0%	81.0%	88.0%

Recent studies showed the infection type traits were also under effect of the other factors such as environmental conditions (temperate, light and relative humidity), plant age and plant feeding. The amount of primary material inoculation and time of inoculation is affected by the factors mentioned earlier.

In present experiment the coefficient of variation was high in resistant components for both Mashhad and Karaj races (11.65 and 19.75, respectively) and mean square of genotypes were significantly different.

Study on 11 varieties of bread wheat showed that low infection types mainly had a correlation with long latent period also in another experiment the negative interaction has been reported by Broers *et al.* (1996) and Wagoire *et al.* (1998).

Saeidi *et al.* (1998) reported that thigh negative correlation between latent period and size and the number of pustule on the leaf surface of few Iranian wheat varieties and three races of yellow rust. Dehghani (2004) during a study on three different types of yellow rust reported that the length of latent period had a significant and negative relationship with infection types and pustule size.

Data analysis by Hayman (1960) and Jinks (1956) methods are shown in Table 5. Regression coefficients of infection type traits subtracted from 1 (B-1) for Mashhad ($4E0A^{+}$) and Karaj ($134E134A^{+}$) races were not significant. This approves the one of the hypothesis of diallel method that emphasizes the absence of non-allelic or epistasis interactions. If parental genes have interactions with other genes, the data points belonging to these parents will be far from regression line (outlier point) so the slope is not equal 1 (Zahravi *et al.*, 2006).

Furthermore we can use graphical analysis in order to recognize the dominant and recessive alleles. The amount of (B-1) for both races in infection type traits were 0.76±0.09 and 0.81±0.21, respectively.

The average of dominant degree for Karaj and Mashhad races were 1.23 and 0.99, respectively. If the average of dominant degree is more than 1 so it is called over dominance. If it is between 1 and 0 so it is called incomplete over dominant. Amount of $\left(\sqrt{\frac{H_2}{4H_1}}\right)$ shows the ratio of genes that have positive and negative effect in their parents. This amount for Karaj race was 0.17 and for Mashhad race was 0.42. If this ratio is near to 0.25 like Karaj race, it means the frequency of dominant and recessive genes are equal. If this ratio is more than 0.25 like Mashhad race, it means the frequency of dominant genes is more than 0.5. Ratio between dominant and recessive gene for infection type traits for both Karaj and Mashhad races were 0.54 and 0.43, respectively and showed that dominant and recessive gene have a similar frequency.

Special combining ability and general combing ability for Karaj ($134E134A^{+}$) race were 97 and 56%, respectively. Low special combining ability shows the importance of dominant effect of gene control to infection type traits. Resulted from Hayman and jenks method showed that the deviation amount of regression coefficient (B-1) for both Karaj ($134E134A^{+}$) and Mashhad ($4E0A^{+}$) was not significant. This meets one of the important hypotheses of diallel method (no interaction of nonallelic or epistazy). If parental genes have an interaction with each other so the data point of this parent will placed as outlier in regression line and slope of regression line is not equal 1 (slop ≠ 1). Therefore the graphical analysis can be used to determine the dominant and recessive alleles. Amount of (B-1) for Karaj ($134E134A^{+}$) and Mashhad ($4E0A^{+}$) in latent period traits were 0.68±0.16 and 0.71±0.6, respectively.

According to D, H_1, H_2 and F parameters for latent period traits of Karaj ($134E134A^{+}$) were 1.51, 2.48, 1.89 and -0.91, respectively. The amount of D is lower than H_1 and H_2 showing that additive component rather than in-additive component which have lower importance in latent period. Results showed when F is negative the importance of recessive alleles was more than dominant alleles (Naghavi *et al.*, 1998). Amount of D, H_1, H_2 and F parameters for latent period traits for Mashhad ($4E0A^{+}$) race were 1.51, 3.4, 2.86, 1.23, respectively. Now the D amount is lower than the H_1 and H_2 amounts and this means additive component rather than in-additive component which has lower importance in latent period traits. Ghannadha (1998) and Zahravar (2006) also

Table 6: Analysis of variance of GCA and SCA for race of Karaj (134E134A+)

SOV	df	Means of square	
		Latent period	Infection type
Replication	2	1.50**	0.48ns
GCA	9	9.80**	17.64**
SCA	35	1.17ns	6.34**
Error	88	1.91	0.37
2GCA/SCA+2GCA	-	0.94	0.85

**Significant at 1% level, ns: Non significant

Table 7: Analysis of variance of GCA and SCA for race of Mashhad (4E0A+)

SOV	df	Means of square	
		Latent period	Infection type
Replication	2	2.30**	0.01ns
GCA	9	11.70**	36.17**
SCA	35	2.21ns	4.48**
Error	88	0.98	0.62
2GCA/SCA+2GCA	-	0.91	0.94

**Significant at 1% level, ns: Non significant

reported the same results. Degree of mean dominance $\left(\sqrt{\frac{H}{D}}\right)$ for Karaj and Mashhad races were 1.28 and 1.53, respectively. Degree of mean dominance was higher than 1 and therefore the gene effect is over dominant, amount of $\left(\sqrt{\frac{H_2}{4H_1}}\right)$ for both Karaj and Mashhad races were 0.44 and 0.46, respectively. Because this ratio was higher than 0.25, it means the frequency of dominant gene is higher than recessive gene. Narrow sense heritability for Karaj and Mashhad races were 0.96 and 0.89 and broad sense heritability for both races were 0.93 and 0.88, respectively. Generally, low amounts of narrow sense heritability show the importance of dominant effect in latent period trait. This also was resulted by Ghannadha and Zahravar (Ghannadha, 1998; Zahravar and Bihamta, 2006).

In diallel analysis by Griffing method the amount of general and special combining abilities for latent period traits have been studied for both races. The latent period trait was significant (Table 6, 7).

The results showed genotypes have high differences in general and special combining abilities. Baker ratio (2GCA/SCA+2GCA) in both Karaj and Mashhad races for latent period traits were 0.94 and 0.91, respectively showing the importance of additive component rater than in-additive component. D amounts lower than H_1 and H_2 confirms the results.

The amount of GCA and SCA for infection type traits for both Karaj and Mashhad pathotype shows significant differences between infection type traits (Table 6, 7). It shows the genotypes have differences in GCA and SCA. Baker ratio for Karaj race was 0.85 and for Mashhad race was 0.94. It shows the importance of additive component is more than in-additive component.

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