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INHERITANCE OF RESISTANCE TO LEAF RUST IN 13 WHEAT NEAR-ISOGENIC LINES

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ABSTRACT

The inheritance of seedling and adult plant resistance against race no 49 of *P. triticina* and more virulent race mixture, was studied under greenhouse and field conditions sequentially. The monogenic line Lr34 was crossed with each of Lr,s : B, 11, 12, 13, 17, 24, 31 and 35.The line Lr10 was crossed with either of Lr9, 23 and 24. Finally the line Lr35 was crossed with each of Lr31 and 38. At seedling stage, the cross Lr34 + Lr24 was segregated in F_2 as ratio 9(R): 7(S), while at adult stage no segregation was observed and the resistance was dominant. Lr35 + Lr38 at seedling and adult stage F_2 segregated to 9 (R): 7(S). On the other hand Lr9 + Lr10 at seedling stage F_2 segregated to 7(R): 9(S), but at adult stage appeared no segregated and dominance of resistance. Likewise Lr10 + Lr23 at seedling stage F_2 segregated to 1(R): 15(S), while adult stage segregated to 13(R): 3(S). The cross Lr34 + Lr35 at seedling stage F_2 showed no segregation, the dominance was in the side of susceptibility, while adult stage segregated to 13(R) : 3(S). The rest crosses of adult stage appeared segregated and dominance tend to the side of susceptibility, but at seedling stage all crosses showed no segregation and dominance tend to the side of susceptibility. This investigation confirmed on studying the genetics of resistance at adult stage that have expression rather than seedling stage.

INTRODUCTION

Wheat leaf rust caused by *Puccinia triticina* (= *P. reconditor Robego vera Desmaz* f. sp. *tritici Eriks.* and *E. henn*.) is among the most important foliar diseases of wheat (*Triticum aestivum* L.).The high resistance to leaf rust of wheat is primarily due to as yet undescribed genes, many of which are expressed at the adult plant stage only (Saini *et al.,* 1988; Singh and Rajaram, 1991; Shiwani and Saini,1993; Kaur *et al.,* 2000). The leaf rust resistance gene Lr34 is associated with durable resistance to the disease (Singh 1992, Singh *et al.,* 1995 and Suenage *et al.,* 2001). Khanna *et al.* (2005) pointed to leaf rust resistance in a cross of HD2009 with WL711 has been ascribed to 2 genes each, which confer non-hypersensitive resistance. The gene conferring non-hypersensitive leaf rust resistance of most monogenic lines have an additive effect.

Disease resistance is controlled by major or minor genes or both together, however, complementary effect between major genes may enhance the response of a variety and another giving high levels of resistance (Simons *et al.,* 1978). Resistance gene expression is dependent on the genetics of host-parasite interaction, temperature conditions, plant development stage and interaction between resistance genes in the wheat genomes (Kolmer, 1996 and Eversmeyer and Karmer, 2000). Therefore, the main objective of this work was to study inheritance of leaf rust resistance through testing 13 (Lr,s) crosses at seedling and adult plant stages.

MATERIALS AND METHODS

The present investigation was carried out at Sakha Agricultural Research Station Experimental Farm, Kafr El-Sheikh and also under greenhouse conditions in Wheat Disease Research Division, Plant Pathology Research Institute at Giza. Egypt.

The cross between leaf rust monogenic lines aimed to searching for complementary or additive genes governing the resistance. The monogenic lines (Lr's) i.e. 34 was crossed with 8 Lr's i.e. B, 11, 12, 13, 17, 24, 31 and 35; Lr35 was crossed with 2 Lr's i.e. 31 and 38; Lr10 was crossed with Lr's 9, 23 and 24; their parents were selected and results in 13 cross. Any doubtful of F1 plants were discarded and the others were separately harvested.

The monogenic lines parents were sown during 2003/2004 growing season in 1.5 m long and 30 cm apart. Each row was sown to 15 seed with distance 10 cm. The experimental unite included 4 row of each parent (Lr's). The monogenic lines were selected according to their susceptibility or resistance on the basis of their reaction to leaf rust in the field during the elapsed growing seasons.

In 2004/2005 growing season, part of the 13 (Lr's x Lr's) crosses hybrid seeds was sown to produce F_1 plants and the other part was left for the final experiment in the next growing season. For the evaluation of parents, F_1 and F_2 plant populations against single race i.e. 49 of leaf rust pathogen caused by *Puccinia triticina* under greenhouse conditions. Routine work of rust was carried out in 2005/2006 growing seasons, for seedling test in the greenhouse of Wheat Disease Research Division. One pot for each of parents and F_1's as well as 13 pots of each of F_2 crosses were sown. Each pot contained 20 seed. Eight days old seedlings of the parents, F_1 and F_2 plant populations were uniformely inoculated with uredinospores of (*P. triticina* f.sp. *tritici*) using race no.49 of the pathogen. For inoculating all tested materials under greenhouse conditions at seedling stage, using the gently rubbing technique described by Stakman *et al.* (1962).

Infection type data against one race has recorded after two weeks from inoculation according to the method described by (Johnston, 1961), i.e. immune = 0, Nearly immune = 0; Resistance = R, Moderately resistance = MR, Moderately susceptible = MR and susceptible = S.

Field test:

Under field conditions, thirteen plots, each included 16 rows, one row for each parent and F_1 as well as 13 row for F_2 plant populations. The row was 2 m long, spaced 30 cm apart and seeds were 10 cm apart within row. Each row was planted by 20 seed. The adjacent plots were separated by a 1 m wide belt. All plots were surrounded by a spreader area of one meter in width, planted with a mixture of the three highly susceptible cultivars to the leaf rust pathogen i.e. Giza 139, Thatcher and little club.

For the field inoculation, the spreader plants were moistured and dusted with spore-powder mixture of the most prevalent leaf rust races in the area (one volume of fresh urediospore mixture: 20 volume of talcum

powder). Dusting was carried out in the early evening at (sunset) before dew formation and when air was still in.

The inoculation of all plants was carried out at booting stage according to the method suggested by Tervet and Cassel (1951).

Data of leaf rust severity were recorded on the adult plant stage of the tested plants according to the modified Cobb Scale (Peterson *et al*., 1948). All regular cultural practices were applied during the growing season.

Data were recorded according to the technical recommendations as rust severity for each plant. Plants were divided into classes according to the level of rust severity i.e. 0-10, 11-20, 21-30, 31-40 and 41-50, 51-60, 61-70 and 71-80. Plants grouped in the first four classes were considered as low phenotypes, while other four classes (more than 40 %) were considered as high phenotypes Negm (2004) and Shahin (2005).

Statistical and genetic analysis:

Frequency distribution values were computed for parental, F_1 and F_2 plant populations for leaf rust infection type and disease severities percentage under greenhouse and field conditions.

In respect to mode of inheritance, goodness of fit of the observed to the expected ratios of phenotypic classes concerning leaf rust infection type and disease severities were determined by X^2 analysis according to Steel and Torrie (1960).

Moreover, the minimum number of effective genes controlling slow-rusting resistance in each cross was estimated by the formula of Wright (1968). Degrees of dominance were calculated according to the method suggested by Romero and Frey (1973). Heritability in its broad-sense was estimated according to Lush (1949).

RESULTS

The present work was carried out to study the inheritance of leaf rust resistance in 13 wheat monogenic lines having different levels of resistance and disease severity.

The obtained data were qualitatively and quantitatively analyzed as follows:

A. Greenhouse tests:

1. Genetic behaviour of certain leaf rust monogenic lines as affected by leaf rust race 49 at seedling stage under greenhouse conditions:

The disease reaction was studied within 13 Lr's crosses including 11 susceptible Lr's i.e B, 10, 11, 12, 13, 17, 23, 24, 31, 34 and 35 and two resistant Lr's i.e. 9 and 38. The thirteen crosses could be arranged into two categories:

The first category:

Data presented in Table (1) revealed that either of the tested parents showed susceptible response against race 49 of leaf rust disease. This response ranged between (3 or 4). The F_1 tested plants showed the same trend since F_1 plants within tested crosses were susceptible except for two crosses which exhibited resistant infection type i.e. (Lr34 x Lr 24) and (Lr35 x Lr38).

T1

1c

The F_2 plant populations showed no segregation with the exception of three crosses that showed segregation i.e. (Lr34 x Lr24), (Lr35 x Lr31) and (Lr10 x Lr23) with resistant: Susceptible infection type were 110: 96, 94.117 and 15: 189, sequentially. These observed ratios fitted the theoretical expected ratios i.e. 9: 7, 7: 9 and 1: 15 with *P. values* i.e. 0.750-0.500, 0.500-0.250 and 0.750-0.500, respectively.

The second group was represented by two crosses. Four parents included 2 susceptible i.e. Lr10 and Lr35 and 2 resistant i.e. Lr9 and Lr38. The F_1 plants showed resistance against the tested race no.49.

The F_2 plant populations were segregated to resistant and susceptible. The dominance of resistance was recorded with one cross (Lr35 x Lr38) where it was 119: 87. This observed ratios fitted the theoretical expected ratio 9: 7 with P. values 0.750-0.500. While the other cross showed susceptible dominance.

B-Field tests:

Evaluation of parents, F_1 and F_2 plant populations against races mixture of *P. triticina* f.sp. *tritici* at adult stage. Data presented in Table (2) indicated that most of the parents: i.e. B, 10, 11, 12, 13, 17, 31 and 35 displayed high infection type (susceptible). While the rest Lr's parents: 9, 23, 24, 34 and 38 exhibited low infection type (partial leaf rust resistance). The thirteen crosses could be arranged into three groups:

The first group LIT/LIT was represented by one cross i.e. (Lr34/Lr24). The F_1 tested plants appeared to have the same trend with their parents. The F_2 plant populations showed no segregations but proved to have partial leaf rust resistance dominance.

The second group included eleven crosses. All F_1 tested plants showed low infection types except for one cross i.e. (Lr34/Lr11) showed high infection type (susceptible). The F_2 populations showed that one out of eleven crosses was not segregated i.e. (Lr9/Lr10) but the dominance tend to partial leaf rust resistance. The rest of crosses appeared to segregate with numbers of plants with low and high infection types i.e. 46/170, 17/229, 18/199, 46/189, 18/232, 46/185, 190/35, 170/36, 16/207 and 115/97, sequentially. These observed ratios fitted the theoretical expected ratios 3: 13, 1: 15. 1: 15, 3: 13, 1: 15, 3: 13, 13: 3, 13: 3, 1: 15 and 9: 7 with P. values 0.500-0.250, 0.750-0.500, 0.750-0.0500, 0.750-0.500, 0750-0.500, 0.750-0.500, 0.250-0.100, 0.750-0.500, 0.500-0.250 and 0.750-0.500, respectively.

The third group HIT/HIT this group included only one cross i.e. (Lr35/Lr31). The F_1 plants exhibited high infection type similar to their parents. The F_2 plant populations were segregated with low/high infection type were 17: 220. This observed ratio fitted theoretical expected ratio i.e. 1: 15 with P. value 0.750-0.500.

II Quantitative analysis:

To study the genetic behaviour of wheat resistance to leaf rust quantitatively, the two parents, F_1 and F_2 plant populations for each of the thirteen crosses were tested at seedling stage under greenhouse conditions against race 49 of *P. triticina* in Table (3).

T2

2c

Also, tested adult stage plants under field conditions against race mixture of the pathogen is clarefied in Table (4). Populations means and variance of the parents, F_1's and F_2's were used to estimate the degrees of dominance for F_1 (h_1) and F_2 (h_2), the heritability in its broad-sense and number of functioning genes for each cross is clarified in (Tables 3 and 4).

Table (3): Means of P_1, P_2, F_1, F_2 and mid-parents, degree of dominance of F_1 and F_2 as well as broad sense heritability for leaf rust infection type of 13 (Lr's x Lr's) crosses at seedling stage inoculated with race no. 49 (*P. triticina*) under greenhouse conditions in 2004/2005 growing season.

No.	Cross name	Mean of infection types					Degree of dominance		Heritability	No. of genes
		P_1	P_2	F_1	F_2	MP	h_1	h_2		
I- S x S										
1	Lr34 / LrB	5.15	5.2	5.3	5.56	5.125	5.0	30.8	33.67	0.0078
2	Lr34/ Lr11	5.15	5.2	5.4	5.573	5.125	9.0	31.84	28.23	0.062
3	Lr34/Lr12	5.15	5.1	5.35	5.574	5.125	9.0	35.82	39.21	0.0189
4	Lr34/Lr13	5.15	5.1	5.4	5.53	5.125	11.0	32.4	39.0	0.031
5	Lr34/Lr17	5.15	5.35	5.45	5.55	5.25	2.0	6.0	19.7	0.5
6	Lr34/Lr24	5.15	5.3	3.1	4.282	5.225	-28.38	-25.147	89.35	0.0022
7	Lr34/Lr31	5.15	5.3	5.4	5.565	5.425	2.33	4.533	23.0	0.281
8	Lr34/Lr35	5.15	5.25	5.65	5.56	5.2	9.0	14.4	27.73	0.054
9	Lr35/Lr31	5.25	5.3	3.95	4.185	5.275	-53.0	-87.0	92.297	0.00014
10	Lr10/Lr23	5.45	5.35	5.1	5.181	5.4	-6.0	-8.76	69.125	0.0024
11	Lr10/Lr24	5.45	5.3	5.9	5.585	5.375	70.0	5.6	24.9	0.018
II- S/R										
12	Lr35/Lr38	5.25	1.702	3.1	2.983	3.476	-0.212	-0.555	93.701	0.388
13	Lr10/Lr9	5.45	3.9	3.95	4.363	4.675	-0.935	-0.805	92.22	0.187

Table (4): Mean of P_1, P_2, F1,F_2, degree of dominance of F_1 and F_2 as well as heritability and number of genes for rust severity % of 13 (Lr's x Lr's) crosses inoculated with race mixture of *P. triticina* under field condition in 2005/2006 growing season.

No.	Cross name	Mean of disease severity					Degree of dominance		Heritability	No. of genes
		P_1	P_2	F_1	F_2	MP	h_1	h_2		
I- LIT/LIT										
1	**Lr34 x Lr24**	**34.0**	**33.0**	**5.0**	**12.0**	**33.5**	**-56.0**	**-84.0**	**83.12**	**0.002**
II- LIT/HIT										
2	Lr34/ Lr24	34.0	64.5	33.5	37.69	49.25	-1.05	-1.54	96.77	0.446
3	Lr34/Lr11	34.0	64.5	45.5	43.62	49.25	-0.246	-9.177	94.83	1.1
4	Lr34/Lr12	34.0	64.5	33.5	42.97	49.25	-1.05	-0.837	93.76	0.903
5	Lr34/Lr13	34.0	64.0	34.5	38.57	49.0	-0.97	-1.37	97.18	0.43
6	Lr34/Lr17	34.0	63.5	33.5	43.52	48.72	-1.034	-0.709	90.5	1.008
7	Lr34/Lr31	34.0	64.5	33.0	38.4	49.25	-1.065	-1.422	96.3	0.5
8	Lr34/Lr35	34.0	63.5	16.0	16.91	48.75	-2.22	-4.317	94.90	0.566
9	Lr34/Lr10	34.0	64.0	16.0	16.64	49.0	-2.254	-4.422	88.32	1.989
10	Lr23/Lr10	33.5	64.0	16.0	17.14	48.25	-2.147	-4.145	95.71	0.505
11	Lr24/Lr10	33.0	64.0	34.5	42.98	48.5	-0.903	-0.712	91.68	1.049
12	Lr38/Lr35	34.0	63.5	26.5	27.74	48.75	-1.508	-2.848	96.40	0.354
III- HIT/HIT										
13	Lr35/Lr31	63.5	64.5	46.5	43.4	64.0	-35.0	-82.4	91.71	0.001

Five out of each thirteen means the infection type for F_1's and F_2's were lower than their respective mid-parent values which were recorded with crosses i.e. (Lr34 + Lr24), (Lr35 + Lr31), (Lr10 + Lr23), (LR35 + Lr38) and (Lr10 + Lr9) at seedling stage (Table 3). While in adult stage, the means of disease severity for F_1's and F_2's were lower than their mid-parents values, these results were recorded with all crosses (Table 4).

Data obtained in Tables (3 and 4) supported the high heritability values which were recorded with crosses exhibited means of infection type F_1's and F_2's lower than their respective mid-parents, were previously mentioned with 5 crosses in Table (3) and all crosses in Table (4). While the low heritability values for the rest eight crosses in Table (3) at seedling stage due to the effect of environmental conditions was the highest effective for those crosses and the dominant alleles were not equally distributed for parents and the vice versa in the case of high heritability.

Number of genes:

Leaf rust infection type or severity, means of parents and variances of F_1's and F_2's were used to quantitatively estimate the number of genes that conditions partial leaf rust resistance in the tested wheat (Lr's).

The minimum number of effective genes controlling resistance at seedling or partial resistance at adult plant stage was digenic for each of the segregated crosses in Tables (1 and 2).

DISCUSSION

Wheat leaf rust caused by *P. triticina tritici* is considered one of the most common wheat diseases. Losses in grain yield due to the disease depend on the host-pathogen interaction in certain areas. However, using effective resistance genes can be considered the economic and desirable method for controlling the disease. For fully utilization of the resistance genes, knowledge about the identity effectiveness and interaction between resistance genes is needed. Such information is very useful in efficient incorporation of different genes into variety for a long lasting resistance. The level of resistance was enhanced when uneffective genes were incorporating in one genotype (Schafer *et al.,* 1963; Baker, 1966; Dyck *et al.,* 1966; Simons *et al.,* 1978; Kolmer, 1992 , Sawhney, 1992, and Sawhny *et al*. 1992). Complementary gene action is commonly used to describe the interdependence of two or more genes or their products, all of which are essential for the ultimate expression of a character (Hooker, 1967). Gene interaction may be also additive, resulted in a higher level of resistance than that conferred by the genes singly (Dyck and Samborski, 1982, Samborski and Dyck, 1982). They showed that the gene combination Lr13 + Lr16, Lr30 + Lr3ka, Lr30 + Lr11 and Lr33+ Lr34 exhibited higher levels of resistance than either of the respective Lr genes alone, especially those expressing adult plant resistance. Sawhney *et al.* (1989) showed that adult plant resistance conferred by both Lr10 and Lr23 is enhanced when presented in "Chinese spring" relative to a "Thatcher" background Lr34 alone produced slow-rusting, but in combination with 2-3 additional genes conferred a high level of resistance (Anonymous, 1990). The allele for Lr9 was effective for all

years, although susceptibility gradually increased. This indicates that the virulence for Lr9 was present before 1970. The Lr9 (TC) was effective in all six continents, while it was effective for controlling leaf rust in Africa, North and South America (Smith and Kilpatric, 1978). The above mentioned results were in accordance with our results obtained here.

Evaluating monogenic lines (Lr's) under field conditions during the elapsed growing season. Most of Lr's i.e. B, 10, 11, 12, 13, 17, 31, 17, 31 and 35 showed susceptibility all over the seasons, while Lr9, 23, 24, 34 and 38 exhibited different levels of partial leaf rust resistance. The obtained results revealed that Lr38 and Lr9 exhibited resistance at seedling stage against race no. 49. Also, they showed partial resistance against more virulent race mixture under field conditions, according to those results adopted by Smith and Kilpatric (1978). On the other hand Lr23, 24 and 34 displayed susceptibility at seedling stage against race no. 49, while they exhibited partial leaf rust resistance at adult stage, according to (Kolmer, 1996, Eversmeyer and Karmer, 2000). The results obtained showed that thirteen crosses were tested at seedling and adult stage. Lr's crosses (Lr 38 + Lr35) and (Lr34 + Lr24) proved their resistance at seedling stage and partial leaf rust resistance at adult stage, according to the findings adopted by Samborski and Dyck (1982). Also, the cross (Lr9 + Lr10), (Lr34 + Lr35) and (Lr23 + Lr10) exhibited partial leaf rust resistance at adult stage under field conditions but there were susceptibility at seedling stage against race no. 49 of leaf rust. This result was in accordance to what adopted by Smith and Kilpatric , 1978; Samborski and Dyck, 1982; Sawhney *et al.,* 1989 and Denisson (1993). The complementary gene action for resistance was found with (Lr34 + Lr24) and (Lr35 + Lr38) at seedling stage, while adult stage was recorded with (Lr38 x Lr35). The inhibitory gene actions for resistance were reported with crosses i.e. (Lr34 x Lr35) and (Lr23 x Lr10). The resistance in this investigation was based on digenic control according to the results adopted by (Samborski and Dyck, 1982; Pederson and Leath, 1988; Roelfs, 1988 and Sayer *et al.,* 1998).

The partial leaf rust resistance due to Lr34 was based on reduced rate of haustorium formation in early stages of infection. If houstoria are formed, the slow mycelial growth may be due to a restricted movement of fungus from one cell to another by a similar phenomenon Rubiales and Niks (1995). The infection type in 17 cultivars was high at seedling stage, therefore they failed to postulate any Lr gene in these cultivars Singh *et al.* (1995). Regarding the quantitative analysis,leaf rust infection type at seedling stage and disease severity at adult stage of F_1 and F_2 plant populations in the thirteen crosses (Lr's) was lower than that calculated for their respective mid-parents for all crosses at adult stage. But at seedling stage under greenhouse conditions only five crosses out of thirteen were lower than their mid-parents, the rest crosses showed low heritability values. The high heritability values were indicative for high rates of success in recovering the desired genes in future segregating generations. However, the low heritability due to the effect of environmental conditions was the highest for that crosses and the dominant alleles which were not equally distributed for parents, and the reverse was noticed in the case of high heritability. Also, these high value

indicate that the selection for this character in early segregating generations could be possible, while delaying it would be more effective. These results are in harmony with those of Kuhan *et al.* (1980), Lee and Shaner (1985), Das *et al.* (1993), Abd El-Latif *et al.* (1995), Shehab El-Din *et al.* (1996), Boulot (1997), Negm (2004) and Shahin (2005).

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وراثة مقاومة صدأ الورقة فى ١٣ سلالة قمح أحادية الجين

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تمت دراسة وراثة المقاومة فى مرحلة البادرة ضد السلالة ٤٩ من فطر بكسينيا تراتيسينا وذلك تحت ظروف الصوبة وضد مخلوط من السلالات الأكثر عدوانية لهذا المسبب المرضى تحت ظروف الحقل. حيث تم تهجين السلالة أحادية الجين Lr_{34} مع LrB, 11, 12, 13, 17, 24, 31 and 35 ، والسلالة Lr_{10} مع Lr_9, 23 and 24 والسلالة Lr_{35} مع Lr_{31} and 38 . فى مرحلة البادرة تم انعزال الجيل الثانى للهجين Lr_{24} + Lr_{34} بنسبة (٩) مقاوم: (٧) قابل للإصابة بينما فى مرحلة النبات البالغ لم يحدث انعزال وكانت المقاومة سائدة. أما الهجين Lr_{35} + Lr_{38} ففى كل من مرحلة البادرة والنبات البالغ فقد انعزل الجيل الثانى إلى (٩) مقاوم: (٧) قابل للصدأ. على الجانب الآخر فقد حدث انعزال فى الهجين Lr_{10} + Lr_9 فى مرحلة البادرة فى الجيل الثانى إلى(٧) مقاوم: (٩) قابل للإصابة ولكن فى النبات البالغ ظهر عدم انعزال وظلت المقاومة سائدة. بالمثل فقد تم انعزال الهجينLr_{23} + Lr_{10} فى مرحلة البادرة إلى(١) مقاوم : (١٥) قابل للإصابة بينما فى النبات البالغ فكان انعزال الجيل الثانى بنسبة (١٣) مقاومة : (٣) قابل للإصابة. وأظهر انعزال الهجين Lr_{35} + Lr_{34} فى الجيل الثانى فى مرحلة البادرة عدم حدوث انعزال وسيادة القابلية للإصابة بينما فى مرحلة النبات البالغ فقد حدث انعزال للجيل الثانى بنسبة (١٣) مقاومة : (٣) قابل للإصابة. باقى الهجن فى طور النبات البالغ حدث انعزال وسيادة القابلية للإصابة ولكن فى طور البادرة لم يحدث انعزال وسيادة القابلية للإصابة. وهذا البحث يشير إلى التأكيد على دراسة وراثة المقاومة فى طور النبات البالغ حيث أنها كانت أكثر واقعية عن طور البادرة.

Table (2): Leaf rust severity (%) frequency distributions of the two parents, F_1 and F_2 plant populations. Phenotypic classes, expected ratios, X^2 and probable values of F_2 populations of 13 (Lr's x Lr's) crosses as affected by inoculation with races mixture leaf rust (*P. triticina*) adult stage under field conditions in 2005/2006 growing season.

No.		No. of tested plants		Disease severity				classes				Observed ratio		Expected ratio	X^2	P. values
				0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	L	H			
I- LIT/LIT																
1	L34 Lr24	P_1	20			2	18									
		P_2	20			4	16									
		F_1	20	19	1											
		F_2	216	90	70	40						200	0	1: 0	0	> 0.99
II- LIT/HIT																
2	L34 LrB	P_1	20			2	18									
		P_2	20						1	19						
		F_1	20			3	17									
		F_2	216	39	7			151	19			46	170	3: 13	0.92	0.500-0.250
3	Lr34 Lr11	P_1	20			2	18									
		P_2	20						1	19						
		F_1	20					19	1							
		F_2	246	16	1			196	33			17	229	1: 15	0.234	0.750-0.500
4	Lr34 Lr12	P_1	20			2	18									
		P_2	20						1	19						
		F_1	20			3	17									
		F_2	217	18				171	28			18	199	1: 15	2.376	0.750-0.500
5	Lr34 Lr13	P_1	20			2	18									
		P_2	20						2	18						
		F_1	20			1	19									
		F_2	235	41	5			161	28			46	189	3: 13	0.101	0.750-0.500
6	Lr 34 Lr17	P_1	20			2	18									
		P_2	20						3	17						
		F_1	20			3	17									
		F_2	250	16	2			199	33			18	232	1: 15	0.345	0.750-0.500

Table (2):Continued.

No.		No. of tested plants		Disease severity				classes				Observed ratio		Expected ratio	X^2	P. values
				0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	L	H			
7	L34 Lr31	P_1	20			2	18									
		P_2	20						1	19						
		F_1	20			4	16									
		F_2	231	40	6			160	25			46	191	3: 13	0.206	0.750-0.500
8	L34 Lr35	P_1	20			2	18									
		P_2	20						3	17						
		F_1	20		18	2										
		F_2	225	95	65	30		32	3			190	35	13: 3	1: 512	0.250-0.100
9	Lr9 Lr10	P_1	20			1	19									
		P_2	20						2	18						
		F_1	20		18	2										
		F_2	207	53	67	87						207	0	1: 0	0	> 0.99
10	Lr23 Lr10	P_1	20			3	17									
		P_2	20						2	18						
		F_1	20		18	2										
		F_2	206	103	34	33		30	6			170	36	13:3	0.214	0.750-0.500
11	Lr24 Lr10	P_1	20			4	16									
		P_2	20						2	18						
		F_1	20			1	19									
		F_2	223	16				188	19			16	207	1: 15	0.528	0.500-0.250
12	Lr 38 Lr35	P_1	20			2	18									
		P_2	20						3	17						
		F_1	20			17	3									
		F_2	212	37	78			81	16			115	97	9: 7	0.338	0.750-0.500
III- HIT/HIT																
13	Lr35 Lr31	P_1	20						3	17						
		P_2	20						1	19						
		F_1	20					17	3							
		F_2	237	16	1			191	29			17	220	1: 15	0.349	0.750-0.500

Table (1): Infection type frequency distribution for parents, F_1 and F_2 plant populations. Phenotypic classes, expected ratio, x^2 and probable values of F_2 population of 13 (Lr's x Lr's) crosses as affected by inoculation with race 49 of leaf rust (*P. triticina*) at seedling stage under greenhouse conditions in 2004/2005 growing season.

No.	Cross name		No. of tested plants	Infection type race 49 leaf rust						Observed ratio		Expected ratio	X^2	P. values
				0	0;	1	2	3	4	Resistant	Susceptible			
I- S x S														
1	L34 LrB	P_1	20					17	3					
		P_2	20					16	3					
		F_1	20					14	6					
		F_2	210					93	117	0	210	0: 1	0	> 0.99
2	L34 Lr11	P_1	20					17	3					
		P_2	20					16	4					
		F_1	20					12	8					
		F_2	213					91	122	0	213	0: 1	0	> 0.99
3	Lr34 Lr12	P_1	20					17	3					
		P_2	20					18	2					
		F_1	20					13	7					
		F_2	205					87	118	0	205	0: 1	0	> 0.99
4	Lr34 Lr13	P_1	20					17	3					
		P_2	20					18	2					
		F_1	20					12	8					
		F_2	209					98	111	0	209	0: 1	0	> 0.99
5	Lr 34 Lr17	P_1	20					17	3					
		P_2	20					13	7					
		F_1	20					11	9					
		F_2	200					91	109	0	200	0: 1	0	> 0.99
6	Lr 34 Lr24	P_1	20					17	3					
		P_2	20					14	6					
		F_1	20			18	2							
		F_2	206		13	45	52	63	33	110	96	9: 7	0.437	0.750-0.500

Table (1):Continued.

No.	Cross name		No. of tested plants	Infection type race no. 49 leaf rust						Observed ratio		Expected ratio	X^2	P. values
				0	0;	1	2	3	4	Resistant	Susceptible			
7	L34 Lr31	P_1	20					17	3					
		P_2	20					14	6					
		F_1	20					12	6					
		F_2	205					89	116	0	205	0: 1	0	> 0.99
8	L34 Lr35	P_1	20					17	3					
		P_2	20					15	5					
		F_1	20					7	13					
		F_2	209					91	118	0	209	0: 1	0	0 > 0.99
9	Lr35 Lr31	P_1	20					15	5					
		P_2	20					14	6					
		F_1	20			1	19							
		F_2	211	10	20	28	36	87	30	94	117	7: 9	0.055	0.500-0.250
10	Lr10 Lr23	P_1	20					11	9					
		P_2	20					13	7					
		F_1	20					18	2					
		F_2	204	1	2	4	8	125	64	15	189	1: 15	0.660	0.750-0.500
11	Lr 10 Lr24	P_1	20					11	9					
		P_2	20					14	6					
		F_1	20					2	18					
		F_2	207					86	121	0	207	0: 1	0	> 0.99
II- S x R														
12	Lr 35 Lr38	P_1	20					15	5					
		P_2	20	3	17									
		F_1	20			18	2							
		F_2	206	48	41	30		80	7	119	87	9: 7	0.290	0.750-0.500
13	Lr10 Lr9	P_1	20					11	9					
		P_2	20			2	18							
		F_1	20			1	19							
		F_2	204	3	20	25	35	91	30	83	121	7: 9	0.777	0.750-0.500