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SIMPLE INHERITANCE OF PARTIAL RESISTANCE TO LEAF RUST IN SIX SPRING WHEAT CULTIVARS

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ABSTRACT

Leaf rust disease affects wheat stems, leaves, and grains can lead up to 20% loss in the yield. The promising wheat breeding programs focusing on developing cultivars that have high-yielding and are resistance in wheat-growing areas where leaf rust is common. The inheritance and genetic nature of partial resistance were studied in six parental Egyptian wheat cultivars i.e., Sakha-93, Gemmeiza-9, Gemmeiza-10, Gemmeiza-11, Sids-12, Sids-13, and their F_1 and F_2 crosses, using qualitative and quantitative analysis methods. The results proved that partial resistance to leaf rust disease in the wheat cultivars was quantitative trait loci, with the dominance effects being more pronounced in its genetic expression. This type of resistance was controlled by one, two or three gene pairs in the adult stage and the heritability in its broad-sense was generally high (ranging from 81.73% to 93.25%). This indicated that the selection of partial resistance materials in the early generation was possible, while it is more effective if delayed, due to the important role of the dominance effects in the expression of this trait.

Keywords: wheat, breeding programs, leaf rust, resistance inheritance.

INTRODUCTION

The most important epidemic of leaf rust disease in Egypt was recorded in 1945 and 1968. (Abd El-Hak TM *et al.*, 1972). The fungus *Puccinia triticina* Eriks. (syn. *P. recondita* Rob. Ex Desm. f. sp. *tritici* Eriks. and Henn.) attacked the leaf blades, and infected the glumes and leaf sheaths in highly susceptible wheat cultivars (Huerta-Espino *et al.*, 2011). Using resistance cultivars has proved to be the most effective method to control this disease because of its cost-effective, environmentally-friendly nature and the long-term strategy to minimize the losses of wheat yield (Kolmer, 2013; Pink, 2002). In recent years, more attention is being paid to resistance regarding its economic value, its stability (under environmental conditions) and its durability (in time). Hypersensitive resistance is controlled by major genes and is usually race-specific (Snyman *et al.*, 2002). Although a high level of resistance may be achieved, this type of resistance is avoided because it is not durable (Whalen *et al.*, 1988). The breeding for resistance genes against leaf rust may be produced singly or in combination with high yielding genes. (Singh *et al.*, 1998) reported that the losses of wheat yield due to leaf rust disease could be reduced to similar levels of those genotypes which are hypersensitive resistant by using partial resistance (PR) because of long-lasting resistance. In genetics, the term horizontal resistance was first used to describe many-gene resistance, which is sometimes also called generalized resistance. This contrasts with the term vertical resistance which was used to describe single-gene resistance (Don, 2004). Unlike vertical resistance, horizontal resistance is entirely independent of each other in genetic terms. In the first round of breeding for horizontal resistance, plants are exposed to pathogens and selected for partial resistance. Those with no resistance die, and plants unaffected by the pathogen have vertical resistance and are removed. The remaining plants have partial resistance and their seed is stored and bred back up to sufficient volume for further testing. These remaining plants are multiple types of partial-

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resistance genes, and by crossbreeding this pool back on itself, multiple partial resistance genes will come together and provide resistance to a larger variety of pathogens for a long time. Adult plant resistance (APR) was characterized by (Zadoks, 1961) as a resistance that is not expressed in the seedling stage and develops during the late stages of the plant age. APR to leaf rust is common and widely used (Stubbs, 1985). In several cultivars, APR proved to be stable and durable for up to 20 years in spite of considerable exposure to rust pathogens (Johnson, 1978; Johnson and Taylor, 1980; Kumar *et al.*, 2014; Qayoum and Line, 1985). APR is a type of hypersensitive resistance in which the plants in the seedling stage show a susceptible infection type (IT), ranging from 7 to 9 on the scale of (McNeal *et al.*, 1971), and in the adult, stage responses range from 0 to 3 (Parlevliet, 1976). Further experience is required to understand the mechanism of APR and concerted efforts have not been made to detect the factors that affect its expression (Kumar *et al.*, 2014; Qayoum and Line, 1985). PR to leaf rust in wheat is exhibited for a long latent period (LP) caused by one, two or three recessive genes (Broers and Jacobs, 1989; Jacobs and Broers, 1989; Lee and Shaner, 1985). LP was the most important component affected the PR as mentioned by (Neervoort and Parlevliet, 1978; Parlevliet, 1975). The objective of this study was to study partial resistance in six parental wheat cultivars i.e., Sakha-93, Gemmeiza-9, Gemmeiza-10, Gemmeiza-11, Sids-12 and Sids-13 and their F_1 and F_2 crosses, using the qualitative and quantitative methods of analysis.

MATERIALS AND METHODS

To determine the level of partial resistance for the tested cultivars, crosses were carried out in 2010/2011 at Qullien-Kafr el-Sheikh, Egypt among the susceptible parents; Sakha-61 and Sids-1 and six resistant cultivars i.e. Sakha-93, Gemmeiza-9, Gemmeiza-10, Gemmeiza-11, Sids-12 and Sids-13 as mother plants (Table 1).

Table 1. The F1 generation resulting from twelve crosses made among two highly susceptible cultivars and six Egyptian wheat cultivars.

No.	Cross name	No.	Cross name
1	Sakha 61 × Sakha-93	7	Sids-1 × Sakha-93
2	Sakha 61 × Gemmeiza-9	8	Sids 1 × Gemmeiza-9
3	Sakha 61 × Gemmeiza-10	9	Sids 1 × Gemmeiza-10
4	Sakha 61 × Gemmeiza-11	10	Sids 1 × Gemmeiza-11
5	Sakha 61 × Sids 12	11	Sids 1 × Sids 12
6	Sakha 61 × Sids 13	12	Sids 1 × Sids 13

All cultivars were grown in three different periods. The F_1 seeds were harvested and kept for growing in the next seasons (2011/2012) in rows of 4 m long and 0.3 m apart and spaced 0.3 m in order to allow production of F_2 seeds. In the 2012 season and the 2013 season, the seeds obtained from F_1 plants were sown as a single seed for individual inspection to calculate their distribution frequencies. All materials were surrounded by 1.5 m belts, served as a spreader of the highly susceptible entries, i.e. "Morocco and *Triticum spleta saharences*". The spreader plants were artificially inoculated, using a virulent pathotype (TTTSP). The inocula (urediniospores) were obtained from a leaf rust greenhouse in Wheat Diseases Research Department, Plant Pathology Research Institute, ARC, and mixed with talcum powder at the rate of 1:20 (w: w) (Tervet and Cassell, 1951). The standard cultural practices were applied during the growing seasons. Data were recorded as the percentage of stem rust severity for each plant. Frequency distributions of leaf rust severity (%) were computed for parents, F_1 and F_2 populations, under field conditions. The disease severity for each plant was recorded according to the following classes: 0-10, 11-20, 21-30, 31-40, 41-50, 51-60, 61-70, and 71-80. The frequency distribution values were calculated for parental lines, F1, and F2 populations to approximate the percentage of leaf rust severity under field conditions. The mode of inheritance, goodness of fit of the observed ratio to the expected ratio of the phenotypic classes, concerning the stem rust severity (%) was determined by χ^2 analysis (Steel *et al.*, 1980). Moreover, the minimum number of effective genes, controlling resistance, were determined by the formula of (Wright, 1968):

$$N = D^2/8\ (VF_2 - VF_1)$$

Where:

N = Minimum number of effective genes
D = $P_1 - P_2$ (the difference between the mean response of the two parents)
VF_1 = Variance of F_1
VF_2 = Variance of F_2

This formula assumes that a linkage, epistasis and dominance is not existent. Furthermore, it assumes each locus has an equal effect and each gene controlling resistance is existent in either parent of the cross.

The degrees of dominance were calculated according to the method suggested by (Romero and Frey, 1973) where the degrees of dominance are symbolized as h^1 and h^2 for F_1 and F_2, respectively:

$$h^1 = (xF_1 - XM\ P)/D \text{ and } h^2 = 2(xF_2 - XM\ P)/D$$

Where:
D = (xh_p – XM P)
xF_1, xF_2 and xh_p are the means of F_1, F_2 and higher parents and XM P is the mid-parent value.

In addition, the F_1 and F_2 means were compared with mid-parent values using a T-test to determine whether the h^1 and h^2 value was significantly different from zero. Heritability in its broad-sense was calculated according to (Lush, 1949) as follows:

$h^2 = V_G/V_P \times 100$

Where:
h^2 = broad- sense heritability
V_G = genotypic variance of F_2 individuals
V_P = phenotypic variance of F_2 individuals
V_E= environmental variance estimated from variation with the non-segregating populations, i.e., Parents and F_1 plants

RESULTS

This part of the study was carried out to study the inheritance of partial resistance in six wheat cultivars (cvs.) i.e., Sakha-93, Gemmeiza-9, Gemmeiza-10, Gemmeiza-11, Sids-12 and Sids-13. The crosses were classified into two groups; the first group contained six crosses between the highly susceptible cultivar Sids-1 and each of the six cvs. The second group contained six crosses between the highly susceptible cultivar Sakha-61 and each of the six cvs. The data are qualitatively and quantitatively analyzed as follows:

Qualitative analysis: The qualitative analysis of the data was carried out according to the response of the tested parents, F_1 and F_2 populations to the leaf rust pathogen in the adult stage under field conditions, using a mixture of the available urediniospores of the pathogen.

Group 1: crosses with Sids-1: The data presented in Table (2) indicate that the parent Sids-1 consistently expressed high susceptibility to leaf rust with disease severity ranging from 61% to 80%, while the six parents showed different levels of leaf rust severity ranging from 0% to 60%. The frequency distribution of the disease severity of the F_2 plants for six crosses ranged from 0% to 70%. Accordingly, the number of plants with low: high severity was 46:156, 88:7, 97:14, 86:19, 81:7 and 65:18, respectively, while the expected ratio was 1:3, 15:1, 13:3, 13:3, 15:1 and 3:1 for the six crosses respectively. This suggests the interaction of two gene pairs in each cross.

Table 2. Leaf rust frequency distribution of F2 crosses among Sids-1 and the six cultivars, parents and F1 at the adult stage, under field condition in 2012/2013 season.

Cross name	No. of tested plants		Rust severity classes (%)							
			0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80
Sids-1x Sakha-93	P_1	32	-	-	-	-	-	-	12	20
	P_2	33	-	-	-	-	10	23	-	-
	F_1	39	-	-	-	-	14	25	-	-
	F_2	202	10	14	22	53	24	43	36	0
Sids-1x Gemm.-9	P_1	34	-	-	-	-	-	-	13	20
	P_2	33	-	15	20	-	-	-	-	-
	F_1	31	-	-	-	14	18	-	-	-
	F_2	95	20	34	34	0	2	2	3	0
Sids-1x Gemm.-10	P_1	30	-	-	-	-	-	13	17	-
	P_2	27	-	-	15	12	-	-	-	-
	F_1	29	-	11	18	-	-	-	-	-
	F_2	111	31	37	29	0	5	0	9	0

Sids-1x Gemm.-11	P_1	30	-	-	-	-	-	-	13	17
	P_2	40	-	22	18	-	-	-	-	-
	F_1	37	10	8	19	-	-	-	-	-
	F_2	105	32	25	29	0	8	11	0	0
Sids-1x Sids 12	P_1	39	-	-	-	-	-	-	19	20
	P_2	35	-	21	14	-	-	-	-	-
	F_1	30	16	14	-	-	-	-	-	-
	F_2	88	33	26	22	3	3	1	0	0
Sids-1x Sids 13	P_1	41	-	-	-	-	-	-	21	20
	P_2	33	20	13	-	-	-	-	-	-
	F_1	36	15	21	-	-	-	-	-	-
	F_2	83	19	27	19	8	5	5	0	0

Group 2: Crosses with Sakha-61: As shown in Table (3), the six parents showed different levels of leaf rust severity - when Sakha-61 was used as a parent - ranging from 0% to 60% where the cv. Sakha-93 had high rust severity ranging from 51% to 70%. The frequency distribution of the six tested crosses reveals that the F_2 plants had a wide range of disease severity from 0% to 80%. Accordingly, the number of plants with low: high severities were, 25:88, 68:12, 91:15, 88:17, 77:14 and 80:15, respectively, while the expected ratio was 13:3 in every tested cultivar except the cross between Sakha-61 and Sakha-93 where the expected ratio was 1:3. These results confirm that at least two interacting gene pairs are controlling leaf rust disease in each of the above two crosses (Table 4).

Quantitative analysis: The genetic behaviour of partial resistance to leaf rust, the two parents, F_1 and an F_2 population of each of the twelve crosses were tested in their adult stages under field conditions. The means of population and variances were used to calculate the degree of dominance for F_1 (h^1) and F_2 (h^2), the heritability in its broad–sense and the number of functioning genes for each cross illustrated in Table (5) and Table (6).

Table 3. Leaf rust frequency distribution of F2 crosses among Sakha-61 and six cultivars, parents and F1 at the adult stage, under field condition in 2012/2013 season.

Cross name		No. of tested plants	Rust severity classes (%)							
			0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80
Sakha-61x Sakha-93	P_1	35	-	-	-	-	-	17	18	-
	P_2	37	-	-	-	-	26	11	-	-
	F_1	38	-	-	17	21	-	-	-	-
	F_2	113	2	11	12	10	24	26	16	12
Sakha-61x Gemm.-9	P_1	34	-	-	-	-	-	17	18	-
	P_2	39	-	-	23	16	-	-	-	-
	F_1	29	-	-	-	11	18	-	-	-
	F_2	80	12	25	31	-	5	5	2	-
Sakha-61x Gemm.-10	P_1	30	-	-	-	-	-	17	18	-
	P_2	41	-	-	13	28	-	-	-	-
	F_1	34	-	-	13	21	-	-	-	-
	F_2	103	17	34	40	-	8	7	-	-
Sakha-61x Gemm.-11	P_1	30	-	-	-	-	-	17	18	-
	P_2	35	-	-	18	17	-	-	-	-
	F_1	30	-	11	19	-	-	-	-	-
	F_2	105	27	29	32	6	6	5	-	-
Sakha-61xSids-12	P_1	39	-	-	-	-	-	17	18	-
	P_2	40	25	15	-	-	-	-	-	-
	F_1	40	16	24	-	-	-	-	-	-
	F_2	91	34	25	18	11	3	-	-	-
Sakha-61x Sids 13	P_1	39	-	-	-	-	-	17	18	-
	P_2	42	-	27	15	-	-	-	-	-
	F_1	39	21	18	-	-	-	-	-	-
	F_2	95	36	24	20	5	5	5	-	-

Table 4. Leaf rust severity phenotypic classes of F2 plants in twelve bread wheat crosses inoculated with *P. triticina* at the adult stage, under field condition in 2012/2013 season.

ss	Cross name	Phenotype		Expected ratio	χ 2	*P* [b]
		L	H			
1	Sids-1x Sakha-93	46	156	1: 3	0.534	0.25-0.010
2	Sids-1x Gemm.-9	88	7	15: 1	0.202	0.750-0.500
3	Sids-1x Gemm.-10	97	14	13: 3	2. 74	0.250-0.100
4	Sids-1x Gemm.-11	86	19	13: 3	0.03	0.750-0.500
5	Sids-1x Sids 12	81	7	15: 1	0.436	0.750-0.500
6	Sids-1x Sids 13	65	18	3: 1	0.485	0.500-0.250
7	Sakha-61x Sakha-93	25	88	1: 3	0.498	0.500-0.250
8	Sakha-61x Gemm.-9	68	12	13: 3	0.738	0.500-0.250
9	Sakha-61x Gemm.-10	91	15	13: 3	1.47	0.250-0.100
10	Sakha-61x Gemm.-11	88	17	13: 3	0.452	0.500
11	Sakha-61x Sids 12	77	14	13: 3	0.677	0.500-0.250
12	Sakha-61x Sids 13	80	15	13: 3	1.065	0.500-0.250

L= Low rust severity > 30%   H= High rust severity < 30%

Pb values higher than 0.05 indicated that no significance of χ 2

Table 5. Leaf rust severity means, variances, degrees of dominance, heritability in its broad sense (%) and the number of genes for the six crosses at the adult stage, under field conditions in 2012/2013 seasons.

Cross name		$\bar{X}$	S^2	Degrees of dominance		Heritability %	No. of genes
				h^1	h^2		
Sids-1x Sakha-93	P_1	71.25	23.43	F_1	F_2		
	P_2	51.96	21.12	-1.06	-4.10	92.42	0.17
	F_1	51.41	23.01	-	-	-	-
	F_2	41.83	293.92	-	-	-	-
Sids-1x Gemm.-9	P_1	71.06	23.87	-	-	-	-
	P_2	20.71	24.48	-0.21	-2.09	85.60	2.21
	F_1	40.62	24.60	-	-	-	-
	F_2	19.52	167.93	-	-	-	-
Sids-1x Gemm.-10	P_1	60.66	24.55	-	-	-	-
	P_2	29.44	24.69	-1.53	-3.18	90.88	0.49
	F_1	21.20	23.54	-	-	-	-
	F_2	20.22	269.99	-	-	-	-
Sids-1x Gemm.-11	P_1	70.66	24.55	-	-	-	-
	P_2	19.50	24.75	-1.08	-1.87	90.37	1.78
	F_1	17.43	72.46	-	-	-	-
	F_2	21.19	255.96	-	-	-	-
Sids-1x Sids 12	P_1	60.25	24.93	-	-	-	-
	P_2	19.00	24.00	-1.45	-2.30	90.33	0.93
	F_1	9.66	24.88	-	-	-	-
	F_2	15.90	253.09	-	-	-	-
Sids-1x Sids 13	P_1	69.87	24.98	-	-	-	-
	P_2	8.93	23.87	-0.94	-1.20	87.61	2.69
	F_1	10.83	24.30	-	-	-	-
	F_2	21.14	197.18	-	-	-	-

Group 1: Crosses with Sids-1: The data presented in Table 5 shows the F_2 mean values in the six crosses between Sids-1 and each of cvs. Sakha-93, Gemmeiza-9, Gemmeiza-10, Gemmeiza-11, Sids-12 and Sids-13 were: 41.83, 19.52, 20.22, 21.19, 15.90 and 21.14, respectively. These means were lower than those calculated for their respective mid parents, thus revealing the presence of partial dominance for low disease severity (partial

resistance). The estimated values for the degree of dominance of F_1 (h^1) were: -1.06, -0.21, -1.53, -1.08, -1.45 and -0.94 for six crosses, in sequence. The significant negative values of h^1 revealed the presence of partial dominance for low disease severity (Table 5) while the estimated values of degrees of the dominance of F_2 (h^2) were highly significant in all the crosses. These values were: -4.10, -2.09, -3.18, -1.87, -2.30 and -1.20. The estimated negative values also suggest the manifestation of partial dominance for low leaf rust disease.

Group 2: Crosses with Sakha-61: This group contains six crosses between Sakha-61 and each of cvs. Sakha-93, Gemmeiza-9, Gemmeiza-10, Gemmeiza-11, Sids-12 and Sids-13. The F2 mean values in every tested cross were lower than those calculated for their respective mid-parents. The means were 46.68, 23.00, 22.07, 20.23, 16.64 and 18.05, respectively (Table 6). This data suggests the existence of partial dominance for low disease severity and the degrees of dominance of F_1 (h^1) were: -3.87, -0.22, -1.05, -1.56, -0.91 and -1.43, respectively. Therefore, these results indicate to the presence of partial dominance for low disease severity in the six studied crosses. Meanwhile, the estimated values of F2 degree of dominance (h2) for these crosses were highly significant negative values. These values were: -2.42, -2.79, -3.38, -3.27, -1.39 and -2.05, respectively. This data suggests the presence of partial dominance for low disease severity (Table 6).

Table 6. Leaf rust severity means, variances, degrees of dominance, heritability in its broad sense (%) and the number of genes for the six crosses at the adult stage, under field conditions in 2012/2013 seasons.

Cross name		X^-	S^2	Degrees of dominance		Heritability	No. of
				h^1	h^2	%	genes
Sakha-61x Sakha-93	P_1	60.14	24.97	F_1	F_2		
	P_2	47.97	20.89	-3.87	-2.42	93.25	0.06
	F_1	30.52	24.72	-	-	-	-
	F_2	46.68	339.65	-	-	-	-
Sakha-61x Gemm.-9	P_1	60.14	24.97	-	-	-	-
	P_2	29.10	24.19	-0.22	-2.79	88.21	0.65
	F_1	41.20	23.54	-	-	-	-
	F_2	23.00	208.5	-	-	-	-
Sakha-61x Gemm.-10	P_1	60.14	24.97	-	-	-	-
	P_2	31.82	21.65	-1.05	-3.38	86.85	0.65
	F_1	31.17	23.61	-	-	-	-
	F_2	22.07	177.29	-	-	-	-
Sakha-61x Gemm.-11	P_1	60.14	24.97	-	-	-	-
	P_2	29.85	24.97	-1.56	-3.27	86.07	0.74
	F_1	21.33	23.22	-	-	-	-
	F_2	20.23	179.22	-	-	-	-
Sakha-61x Sids 12	P_1	60.14	24.97	-	-	-	-
	P_2	8.75	23.43	-0.91	-1.39	81.73	3.04
	F_1	11.00	24.00	-	-	-	-
	F_2	16.64	132.44	-	-	-	-
Sakha-61x Sids 13	P_1	60.14	24.97	-	-	-	-
	P_2	18.57	22.95	-1.43	-2.05	88.15	1.22
	F_1	9.61	24.85	-	-	-	-
	F_2	18.05	202.26	-	-	-	-

Variances and heritability estimates: The values of the F_2 variances were higher for every studied cross. These values are: 293.92, 167.93, 269.99, 255.96, 253.09, 197.18, 339.65, 208.5, 177.29, 179.22, 132.44 and 202.26. On the other hand, the estimated heritability in its broad sense, calculated from the variance of parents, F_1 and F_2 for twelve crosses are presented in Tables 5 and 6. The heritability values for all the tested crosses are high as the values were: 92.42%, 85.60%, 90.88%, 90.37%, 90.33%, 87.61%, 93.25%, 88.21%, 86.85%, 86.07%, 81.73% and 88.15% for the above mentioned twelve crosses, respectively (Figure 1).

Number of genes: The minimum number of effective genes controlling the partial resistance was digenic for each of the tested crosses of the first group. The estimated number of genes was high for the crosses between Sids-1 and each of Sids-13, Gemmeiza-9, Gemmeiza-11 and Sids-12. On the other hand, the number of genes was low for crosses between Sids-1 and each of Sakha-93 and Gemmeiza-10, indicating that partial resistance between the two crosses does not exist (Table 5). The results obtained from the second group reveal that the differences between every two parents are controlled by two or three gene pairs as the calculated numbers of genes were: 0.65, 0.65, 0.74, 3.04, 1.2 for crosses between Sakha-61 and each of cvs. Gemmeiza-9, Gemmeiza-10, Gemmeiza-11, Sids-12 and Sids-13, respectively. However, the estimated number of genes was low in the cross between Sakha-61 and Sakha-93 (0.06) indicating that partial resistance between the two parental cultivars does not exist (Table 6 and Figure 1).

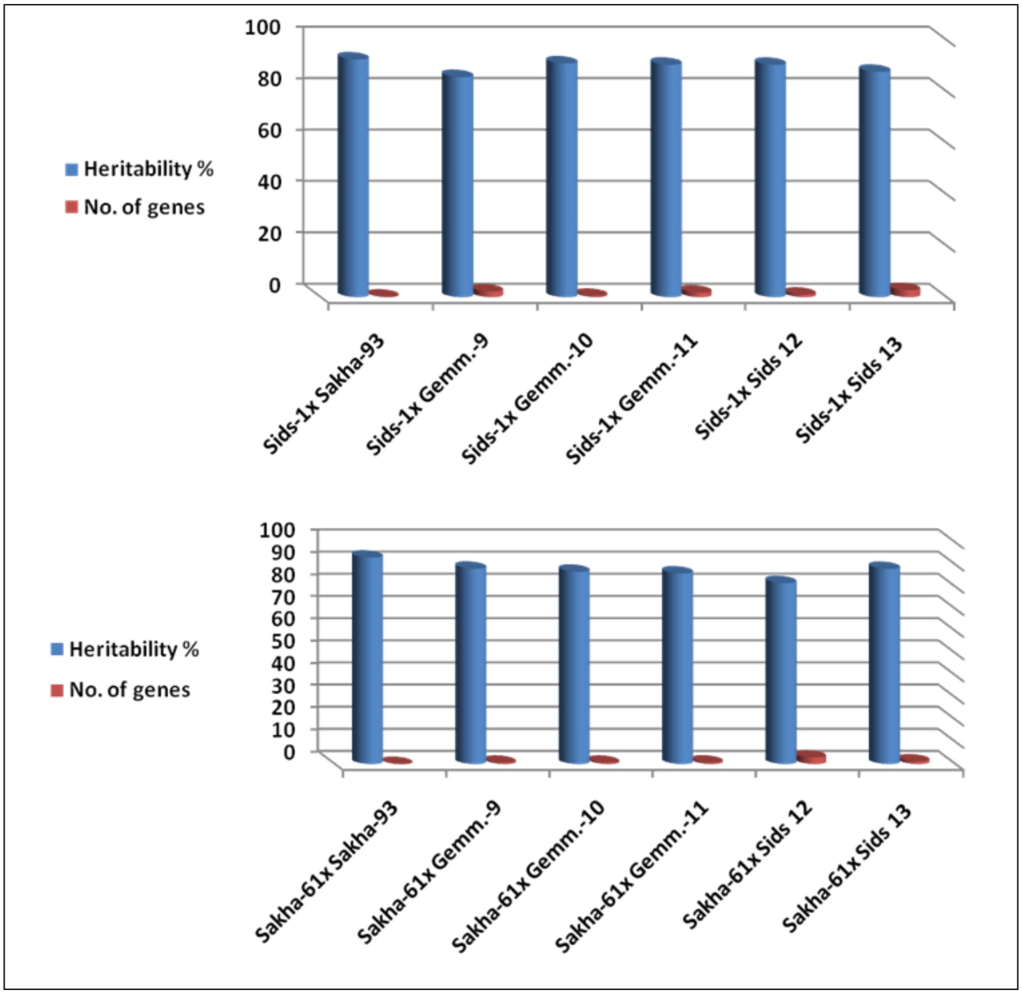

Figure 1. The heritability (%) and the number of genes in the F2 progeny of twelve crosses between two susceptible cultivars (Sids-1 and Sakha-61) and six wheat cultivars.

DISCUSSION

Breeding for disease resistance is a continuous process, thus plant breeders need to add new effective genes to their breeding materials. This study deals with new types of resistance that can be added to wheat to prevent heavy yield losses caused by the leaf rust disease. In the field, hypersensitive resistance, APR or temperature sensitive resistance is often difficult to discern from partial resistance (Broers, 1989; Van Dijk *et al.*, 1988). The results show that the Egyptian wheat varieties (Sakha-93, Gemmeiza-9, Gemmeiza-10, Gemmeiza-11, Sids-12 and Sids-13) exhibited adult plant resistance. The F2 population in the twelve crosses has a wide range of disease severity (0-80%). Furthermore, the observed low: high disease severity ratios of the F_2 population matched the expected theoretical ratios when one, two, three gene pairs are operating. Consequently, this result may add a depth of their resistance to be exploited as good sources of resistance. These results were in accordance with (Herrera-Foessel *et al.*, 2008) who said that slow-rusting resistance to leaf rust in durum wheat lines 'Playero', 'Planeta', and 'Trile' was controlled by at least three independently inherited genes that interacted in an additive manner, whereas the slow-rusting resistance in 'Piquero', 'Amic', 'Bergand', 'Tagua', and 'Knipa' was determined by at least two genes with additive effects. showed that the crosses between RL6008, Hobbit, Fundin and Tara with the susceptible check Armada segregated in 1:2:1 ratio in F_3 progenies. He suggested that a single gene for resistance to leaf rust is present. On the other hand, the crosses between cultivar Tara and the susceptible control Armada segregated 3:1 ratio in the F_2 population when tested with isolate WBRP 82-1. Furthermore, this suggests the presence of a single gene for resistance in Tara. The quantitative analysis of the obtained data reveals that means of F_2 leaf rust severity in the twelve crosses were, in general, lower than the estimated means for their respective mid-parents. These results reveal that partial dominance for low disease severity is present in every cross. The estimated values of degrees of the dominance of F_2 (h^2) were significant, but they were not significant in the other crosses. These results support the manifestation of the partial dominance of low leaf rust disease and confirm the above conclusion. The estimated heritability is generally high which indicates that the selection for partial resistance in the early generation is possible while delaying it, might be more effective due to the important role of dominance effect in the expression of this trait (Adel-Latif AH and El-Dein, 2000). Partial resistance of wheat indicates to a longer incubation period (IP) and longer latent period (LP). PR is assumed to be more stable because of its polygenically inheritance (Parlevliet, 1978) and insensitivity to temperature (Parlevliet and Van Ommeren, 1975). (Rubiales and Niks, 1995) reported that the PR could be better expressed at low temperature. PR is distinguished by a dwindling epidemic development despite a susceptible IT (Parlevliet, 1975). In barley (*Hordeum vulgare* L.) infected by leaf rust (caused by *P. hordei* Otth.), PR is associated with a long latency period (LP), a low infection frequency (IF) and minimal spore production and a short infectious period (Neervoort and Parlevliet, 1978; Parlevliet and Van Ommeren, 1975). It is concluded that the durable resistance against wheat leaf rust can be achieved through the incorporation of partially resistant minor genes. This approach is more suitable as it is a stable solution for sustainable wheat production as well as the gene pyramiding providing acceptable long-term resistance to wheat leaf rust with an emphasis on the important role of PR genes.

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