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INHERITANCE OF ADULT PLANT RESISTANCE TO LEAF RUST IN FIVE EGYPTIAN BREAD WHEAT CULTIVARS

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ABSTRACT

The inheritance of wheat resistance to leaf rust caused by *Puccinia triticina* (Rob. Ex. Desm) was studied under field conditions at El-Nubaria Agric. Res. Station during 2003/04, 2004/05 and 2005/06 growing seasons. Ten crosses were made among the five Egyptian bread wheat cultivars, *i.e.* Sakha 94, Gemmeiza 9 and Giza 168 (resistant), Gemmeiza 7 (moderately resistant) and Giza 139 (highly susceptible) to determine quantitatively the inheritance mode and gene action of leaf rust resistance. The F_1's and F_2's of the ten crosses and their respective parents were evaluated for adult-plant response to leaf rust infection under field conditions at El-Nubaria during 2005/06 growing season, using three components of resistance, *i.e.* FRS (%), r-value and AUDPC.

Analysis of variance (ANOVA) for combining ability effects showed highly significant variance due to general combining ability (GCA) and specific combining ability (SCA) effects for the three leaf rust resistance components, revealing the importance of additive as well as non-additive type of genetic variance in controlling the inheritance of these traits. Nevertheless, the higher values for the GCA variance than those of SCA variance indicated the predominance of an additive component over the dominant one for the three leaf rust resistance parameters; FRS (%), r-value and AUDPC. This result is in conformity with that, the additive component (D) of genetic variance was greater in its magnitude than their corresponding dominance values (H_1) and (H_2), suggesting the importance of additive gene action in the inheritance of wheat leaf rust resistance components of the study and confirmed the above result.

The average of dominance $(H_1/D)^{½}$ was less than unity for each component of resistance, which indicated that presence of partial dominance in the expression of wheat resistance to leaf rust. However, due to the positive values of (F), it could be suggested that the resistant cultivars in the half-diallel crosses seem to carry more dominant alleles than recessive ones for leaf rust resistance. In addition, there are at least two functioning groups of gene pairs controlling the two epidemiological parameters AUDPC and r-value in both F_1 and F_2. Meanwhile, final rust severity (FRS%) was governed by three gene pairs in F_1 and F_2. High heritability values in each broad and narrow sense were estimated for the three adult-plant resistance components. Thus, selecting resistant genotypes may be useful in the early generations, but it would be more effective if delayed to the later ones.

INTRODUCTION

Leaf rust caused by *Puccinia triticina* is considered to be the most common disease of the three wheat (*Triticum aestivum* L.) rusts, due to a relatively high adaptability, over a wide range of environments (Kolmer, 1996). However, it has an annual widespread occurrence in most governorates of Egypt, causing substantial losses in grain yield of the susceptible wheats, particularly during epidemic years (Nazim *et al.*, 1983).

Furthermore, it was the cause of eliminating and discarding many wheat cultivars, rapidly after their release and widely grown, under Egyptian conditions, *i.e.* Giza 139 and the introduced Mexican varieties; Mexipak 69 and Chenab 70. Nevertheless, genetic resistance or the use of resistant cultivars is, still, the most effective, environmentally sound and reliable method to reduce yield losses and avoiding the occurrence of sever leaf rust epidemics (Shehab El-Din *et al.*, 1996; Sayre *et al.*, 1998 and Pink, 2002).

Genetic studies have been performed to give a better understanding on the genetic nature and the inheritance mode as well as the patterns of gene action, controlling rust resistance in wheat genotypes. In most of these studies, it was suggested that, adult-plant resistance to leaf rust was highly heritable trait. The relatively high heritability values for this type of resistance have been documented by Shehab el-Din *et al.*, 1996; Ageez and Boulot, 1999; Boulot and El-Sayed, 2001; Mahgoub, 2001; Navabi *et al.*, 2003 and 2005). In addition, several investigators proved that adult-plant resistance is a quantitatively inherited trait, is influenced by many gene pairs and environmental conditions (Statler, 1984; Pretorius *et al.*, 1990; Mc Intoch, 1992; Watkins *et al.*, 1995; Singh *et al.*, 2000; Navabi *et al.*, 2005 and Singh *et al.*, 2005). In contrast, others stated that resistance is a simple character governed by one, two or few number of genes (Ezzahiri and Roelfs, 1989; Rizivi *et al.*, 1990; Abd El-Latif *et al.*, 1995; Barcellos *et al.*, 2000 and Kolmer and Liu, 2001).

It is generally assumed that, host resistance was dominant over susceptibility in most interactions (Kolmer and Dyck, 1994; Shehab El-Din *et al.*, 1996; Boulot and El-Sayed, 2001 and Awaad *et al.*, 2003). Whereas, the reverse was true in others (Hongtas and Knott, 1990; Ali *et al.*, 1994; Ageez and Boulot, 1999 and Barcellos *et al.*, 2000). Moreover, adult-plant resistance to leaf rust found to be controlled by both additive and non-additive gene effects, but the additive model was more pronounced and had an important role in the inheritance of some crosses (Ageez and Boulot, 1999; Singh *et al.*, 2000; Awaad *et al.*, 2003; Navabi *et al.*, 2003 and Navabi *et al.*, 2005).

Information on the genetic behaviour of this type of resistance to leaf rust in the breeding genotypes, is essential to improve the efficiency of developing new resistant cultivars. Also, to maximizing the genetic improvement of this trait and finally give a high protection against this disease. Therefore, the present study was initiated to assess the mode of inheritance, gene actions and number of functioning gene pairs controlling the adult-plant resistance to leaf rust in five local wheat cultivars commercially grown in Egypt.

MATERIALS AND METHODS

The field experiments of the present study were conducted at El-Nubaria Agricultural Research Station, during the three successive growing seasons;

2033/04, 2004/05 and 2005/06. Five bread wheat cultivars (*Triticum aestivum* L.), were selected for this study, on the basis of their diversity in origin and in leaf adult-plant resistance (Table, 1). These genotypes included the wheat cv.; Giza 139, which used as the highly susceptible parent, and the cvs.; Giza 168, Sakha 94 and Gemmiza 9 (having different levels of adult-plant resistance). Meanwhile, the wheat cv.; Gemmeiza 7 was selected as the intermediate parent. All possible crosses were made among the five parents (without reciprocals), to produce the hybrid seeds of 10 F_1 crosses, during the first growing season (2003/204). In 2004/05, part of each of 10 F_1 seeds were sown to produce F_2 seeds; while others were left for the final experiment in the next season. In 2005/06 growing season, cultivars and their F_1's and F_2's were evaluated for their levels of adult-plant resistance to leaf rust infection, under field conditions.

A comparative experiment was carried out in a randomized complete block design with four replicates. Each replicate contained on row for each parent and F_1, as well as 20 rows for each F_2 cross. The rows were 4 m long and 30 cm apart. Every row contained 20 seeds, spacing 20 cm. The experiment was surrounded by 2 m width spreader, grown with a mixture of the highly susceptible wheat cvs. to leaf rust, *i.e.* Giza 160, Giza 139, Thatcher ..... etc. The spreader plants were subjected to an artificial inoculation with a mixture of freshly collected urediniospores of the most prevalent leaf rust pathotypes. The inoculation was carried out at booting stage, according to the method of Tervet and Cassel (1951). Upon the appearance of symptoms on 50% of the spreader plants, the genotypes were evaluated for rust severity (%), using the modified Cobb's scale (Peterson *et al.*, 1948) at weakly intervals during the season. For quantitative analysis, field response was estimated using the following three disease parameters:

1. Final rust severity (FRS %) as outlined by Das *et al.* (1993). It was recorded as the disease severity (%) when the highly susceptible (check) variety was severely rusted and the disease rate reached the highest and final level of leaf rust severity.
2. Area under disease progress curve (AUDPC) according to the equation of Pandey *et al.* (1989).
3. Rate of disease increase (r-value), was estimated, using the formula of Van der Plank (1984).

All data were subjected to diallel and biometrical analysis. The analysis of variance for both general and specific combining abilities (GCA and SCA) and their effects were performed according to the methods (half dialllel + parents), model 1 (fixed effects of genotypes), as proposed by Griffing (1956). Furthermore, the ratio of GCA variance to SCA variance was estimated as indicated by Singh and Choudhary (1977).

The genetic variance components and different genetic ratios were calculated according to Hayman (1954). Also, heritability in its broad- and narrow-senses were estimated by using the formula of Mather and Jinks (1982).

RESULTS AND DISCUSSION

The nature of genetic variation of leaf rust resistance was investigated in five parental wheat cultivars, having different levels of field response to *Puccinia triticina* (Table, 1). Data obtained indicated that, mean squares of genotypes; parents and the resultant crosses, were found to be highly significant for all studied characters (Table, 2). The significance of the mean squares, indicated the presence of considerable genetic variation among them in their leaf rust resistance components studied. Thus, this variation would insure the validity of the comparisons among the means of these genotypes for all studied characters.

Table 2: Analysis of variance for three epidemiological parameters of leaf rust resistance in five parental wheat cultivars as well as their F_1's and F_2's progenies.

Source of variation (SV)	Degrees of freedom (df)	Generation	Mean squares estimates (MS) for FRS (%) [a]	AUDPC [b]	r-value [c]
Replicates	3	F_1	42.64	3207.92	0.00033
		F_2	11.52	4819.67	0.00036
Genotypes	14	F_1	1773.39**	294811.22**	0.01357**
		F_2	1560.73**	307181.31**	0.01086**
- Parents (P)	4	F_1	3645.00**	726049.38**	0.02475**
		F_2	3645.00**	726049.38**	0.02475**
-Crosses (C)	9	F_1	805.28**	77892.58**	0.00978**
		F_2	671.13**	143986.00**	0.00278*
-(P) VS (C)	1	F_1	3000.00**	522126.25**	0.00300*
		F_2	1230.08**	100467.00**	0.02700**
Error		F_1	31.33	4697.98	0.00048
	42	F_2	17.90	3224.33	0.00029

[a] FRS (%): Final rust severity (%).
[b] AUDPC : Area under disease progress curve.
[c] r-value : Rate of disease increase.
* and ** : Significant at $p<0.05$ and 0.01, respectively.

General and specific combining ability:

The analysis of variance for combining ability showed that both, general and specific combining ability (GCA and SCA, respectively) variances, were significant for all studied characters in both F_1 and F_2 generations (Table, 3). The GCA/SCA ratio, was more than unity in most characters. These results indicated that both additive and non-additive gene effects were of greater importance in the inheritance of those characters. Similar results were previously reported by Jacobs and Broers (1989), Shehab El-Din *et al.* (1996), Agees and Boulot (1999) and Mahgub (2001).

Table 3: Mean squares (MS) for general combining ability (GCA) and specific combining ability (SCA) of five parental wheat cultivars and their F_1's and F_2's progenies.

Source of variation (SV)	Degrees of freedom (df)	F_1's & F_2's progenies	Mean squares estimates (MS) for		
			FRS (%) [a]	AUDPC [b]	r-value [c]
GCA	4	F_1	1204.69**	177749.22**	0.00850**
		F_2	1138.07**	230781.14**	0.00675**
SCA	10	F_1	138.71**	32084.24**	0.00140**
		F_2	91.03**	15201.01**	0.00100**
Error	42	F_1	8.69	5.54	6.07
		F_2	12.50	15.18	6.75

[a] FRS (%): Final rust severity (%).
[b] AUDPC : Area under disease progress curve.
[c] r-value : Rate of disease increase.
* and ** : Significant at p<0.05 and 0.01, respectively.

Highly significant negative estimates of general combining ability effects were found in both F_1 and F_2 progenies of the parental cultivars; Giza 168, Gemmeiza 9 and Sakha 94, with one exception. Meanwhile, the two parental cvs. Giza 139 and Gemmeiza 7, exhibited significant positive values in most traits, under study (Table, 4).

Table 4: Estimates of general combining ability effects (GCA) for the five parental wheat cultivars, evaluated under natural infection of *Puccinia triticina*.

Source of variation (SV)	F_1's & F_2's progenies	General combining ability estimates & disease parameters		
		FRS (%) [a]	AUDPC [b]	r-value [c]
Giza 139	F_1	18.54**	250.56**	0.047**
	F_2	17.32**	288.13**	0.045**
Gemmeiza 7	F_1	8.18**	66.09**	0.020**
	F_2	8.70**	60.14**	0.016**
Sakha 94	F_1	- 10.04**	- 100.94**	- 0.021**
	F_2	- 7.49**	- 102.67**	- 0.012**
Gemmeiza 9	F_1	- 3.96**	- 85.84**	- 0.003**
	F_2	- 4.43	- 75.14**	- 0.014**
Giza 168	F_1	- 12.71**	- 129.87**	- 0.045**
	F_2	- 14.10**	- 170.45**	- 0.035**
L.S.D. gi 5%	F_1	1.89	23.17	0.0007
	F_2	1.43	19.20	0.0006
1%	F_1	2.52	30.82	0.0009
	F_2	1.90	25.53	0.0008
L.S.D. gi-gj 5%	F_1	2.99	36.64	0.0012
	F_2	2.26	30.35	0.0009
1%	F_1	3.98	48.73	0.0016
	F_2	3.01	40.37	0.0012

[a] FRS (%): Final rust severity (%).
[b] AUDPC: Area under disease progress curve.
[c] r-value : Rate of disease increase.
* and ** : Significant at p<0.05 and 0.01, respectively.

However, significant GCA values were evident to the importance of additive and/or additive x additive genes effects. In additions, the results in Table (4), indicated that the cultivars; Giza 168, Gemmeiza 9 and Sakha 94 were sequently, the good combiners for resistant to leaf rust and after the best possibilities for exploitation in the improvement of leaf rust resistance, through hybridization (Griffing, 1956; Mahgoub, 2001 and Lal-Ahamed *et al.*, 2004). In contrast, Giza 139 and Gemmeiza 7 cultivars were poor general combiners for those traits.

As indicated in Table (5), the estimates of SCA effects were significantly negative for the three of resistance components to leaf rust in only five out of the ten crosses in F_1 and F_2 generations. However, the highest four negative values were detected in the crosses; Giza 139 x Giza 168, Gemmeiza 7 x Giza 168, Giza 139 x Sakha 94 and Sakha 94 x Giza 168, in sequence. These results proved the role of non-additive gene action in the inheritance of the tested leaf rust resistance components and at the same time, confirmed that delaying selection of resistant plants to the later generations would be more profitable. Similar results were obtained by Shehab El-Din *et al.* (1996); Ageez and Boulot (1999); Mahgoub (2001) and Navabi *et al.* (2005).

The estimated variance of the genetic components for all studied characters in F_1 and F_2 generations, are presented in Table (6). As indicated from this table, the additive component of genetic variance (D) and the dominance effect (H_1) estimates, were highly significant for all leaf rust resistance components in F_1 and F_2 generations. In addition, the dominance variance indicating genetic distribution among parents (H_2) was positive and highly significant, but smaller than H_1, reflecting unequal allel frequency among parents. Also, this means that dominance seemed to be acting in the positive direction. Furthermore, the positive and highly significant F values indicated that dominant genes were more frequent than the recessive ones among parental genotypes. The measures of the dominance variance overall heterozygous loci (h_2) were positive and highly significant for all leaf rust resistance components in F_1 and F_2 generations, indicating the highest prevalence of dominant effects overall loci, and at the same time, suggesting the importance of dominant effect in all crosses.

From the obtained results shown in Table (6), it could be generally stated that, both additive and dominance gene effects were of great value in the genetic expression of wheat reaction to leaf rust. Similar results were previously found by Jacobs and Broers (1989), Shehab El-Din *et al.* (1996), Ageez and Boulot (1999), Mahgoub (2001), Boulot and El-Sayed (2001) and Lal Ahamed *et al.* (2004), which reported that the inheritance to leaf rust in wheat showed all three types of gene action, i.e. additive, dominance and epistasis.

Degree of dominance:

As indicated in Table (7), the estimated mean degree of dominance overall loci $(H_1/D)^{½}$, was less than unity, for all leaf rust resistance components in both F_1 and F_2 generations. This result indicated the presence of partially dominance gene actions in the inheritance of adult-plant resistance to leaf rust infection, under field conditions.

Table 5: Estimates of specific combining ability effects (SCA) for the ten F_1 and F_2 crosses, evaluated for leaf rust resistance and its components, at adult stage, under field conditions of El-Nubaria Agric. Res. Station.

F_1's & F_2's crosses			Estimates of specific combining ability (SCA)		
			FRS (%) [a]	AUDPC [b]	r-value [c]
Giza 139 x Gemmeiza 7		F_1	0.54	- 26.13	0.016
		F_2	- 2.49	8.78	- 0.031
Giza 139 x Sakha 94		F_1	- 13.75**	- 250.34**	- 0.036**
		F_2	- 7.68**	- 146.09**	- 0.030**
Giza 139 x Gemmeiza 9		F_1	- 4.82	- 128.95	0.016
		F_2	- 5.30**	14.13	- 0.017
Giza 139 x Giza 168		F_1	- 17.32**	- 263.41**	- 0.067**
		F_2	- 17.55**	- 247.25**	- 0.040**
Gemmeiza 7 x Sakha 94		F_1	- 2.14	- 93.00	- 0.024
		F_2	- 1.72	- 47.93	- 0.021
Gemmeiza 7 x Gemmeiza 9		F_1	- 1.96	- 12.73	0.022
		F_2	0.33	19.56	- 0.005
Gemmeiza 7 x Giza 168		F_1	- 8.21**	- 76.32*	- 0.032**
		F_2	- 8.62**	- 74.40*	- 0.025**
Sakha 94 x Gemmeiza 9		F_1	- 0.09	37.05	- 0.002
		F_2	1.05	61.86	0.004
Sakha 94 x Giza 168		F_1	- 6.25*	- 98.71	- 0.032**
		F_2	- 6.06*	- 75.40	- 0.022**
Gemmeiza 9 x Giza 168		F_1	1.43	55.48	0.035
		F_2	3.90	46.19	0.003
L.S.D. Sij	5%	F_1	5.18	63.46	0.020
		F_2	3.92	52.57	0.016
	1%	F_1	6.89	84.40	0.027
		F_2	5.21	69.92	0.021
L.S.D. Sij-Sik	5%	F_1	7.33	89.74	0.030
		F_2	5.54	74.35	0.020
	1%	F_1	9.75	119.36	0.040
		F_2	7.37	98.88	0.030
L.S.D. Sij-Skl	5%	F_1	6.69	81.92	0.020
		F_2	5.06	67.87	0.020
	1%	F_1	8.90	108.96	0.030
		F_2	6.73	90.27	0.027

[a] FRS (%): Final rust severity (%).
[b] AUDPC : Area under disease progress curve.
[c] r-value : Rate of disease increase.
* and ** : Significant at $p<0.05$ and 0.01, respectively.

Estimation of genetic variance components: The proportion of genes with positive and negative effects in the parental genotypes ($H_2/4H_1$), was also calculated for all the studied traits in F_1 and F_2 generations. In general, the values of ($H_2/4H_1$) ratio, were less than 0.25 in both F1 and F2, reflecting unequal distribution of genes with positive and negative effects among the parents and confirmed the results, previously obtained from H_2 estimates. However, the asymmetry of the gene distribution could be due to the significant differences among the parental geotpyes.

In addition, the ratios of dominant genes to recessive ones in the parents (Dom./Res.) were also estimated and presented in Table (7). This ratio was; 1.39 for FRS%, 1.58 for AUDPC and 1.27 for r-value, in F_1, while, it was 1.47 for each of FRS% and AUDPC and 1.51 for r-value in the F_2 generation. This result confirmed the results obtained from the positive F estimates, since both indicated that the five parental genotypes of the study carry more dominant genes than recessive ones, for controlling the studied leaf rust resistance components.

Table 7: Ratio of genetic components in F1 and F2 of a five diallil wheat cross, for three leaf rust resistance components, evaluated under field conditions at El-Nubaria Agric. Res. Stn.

Ratio of genetic components	Crosses	Values of ratios for:		
		FRS (%) [a]	AUDPC [b]	r-value [c]
$(H_1/D)^{½}$	F_1	0.6964	0.8027	0.9621
	F_2	0.6148	0.5863	0.7222
$(H_2/4H_1)$	F_1	0.2207	0.1929	0.1882
	F_2	0.1892	0.1822	0.1887
(KD/KR)	F_1	1.3149	1.5786	1.2712
	F_2	1.4679	1.4714	1.5082
h_2/H_2	F_1	2.340	2.002	1.143
	F_2	2.255	2.182	2.038
Heritability:				
H_{bs} (%)	F_1	98.23	98.41	96.60
	F_2	98.85	98.96	97.36
H_{ns} (%)	F_1	74.52	62.02	66.57
	F_2	80.38	82.77	96.31

[a] FRS (%) : Final rust severity (%).
[b] AUDPC : Area under disease progress curve.
[c] r-value: Rate of disease increase.

Number of genes controlling leaf rust resistance:

Number of the effective factors controlling the three wheat leaf rust resistance components under study, estimated by the ratio (h_2/H_2), were more than unity in both F_1 and F_2 generations (Table, 7). As indicated from this table, the h_2/H_2 values were (2.340 and 2.255), (2.002 and 2.182) and (1.143 and 2.038) for FRS%, AUDPC and r-value characters in F_1 and F_2 generations, respectively. On the basis of these results, it is clear that the above three components of resistance are controlled by 3, 2 and 2 pairs of genes, respectively.

In fact, inheritance of wheat resistance to rusts, especially leaf rust is a debatable issue. It had been reported to be a simple inherited trait controlled by one, two or a few number of gene pairs, by some investigators (Shehab El-Din *et al.*, 1996). Meanwhile, simple and additive inheritance of adult-plant resistance with the involvement of and a few minor additive genes is well documented for leaf rust resistance by Ezzahrii and Roelfs (1989), Rizivi *et al.* (1990), Abd EL-Latif *et al.* (1995) and Kolmer and Liu (2001).

On the other hand, such resistance proved to be a quantitative trait governed by many gene pairs and influenced, to some degree, by environmental conditions, in other reports (Das *et al.*, 1993; German and Kolmer, 1992; Sing and Rajaram, 1992; Shaner *et al.*, 1997). Recently, Lal-Ahamed *et al.* (2004) suggested a polygenic mode of inheritance to leaf rust in wheat using AUDPC, which is in conformity with the reports of Singh *et al.* (2005). Since they proved that at least 10 -12 different leaf rust resistance genes are involved in theAPR of group of CIMMYT wheats. In addition, Navabi *et al.* (2005) in their genetic studies, showed that leaf rust resistance in wheat is a complex trait conditioned by several genes with additive effets.

Heritability:

Estimates of heritability in its broad sense (Hb) and narrow sense (Hn) were computed for all leaf rust resistance components, under study (Table, 7). However, high heritability values in broad sense were estimated for all components of resistance in F_1 and F_2 generations. The broad sense heritability values in F_1 were 98.23%, 98.41% and 96.60%, estimated for FRS%, AUDPC and r-value, respectively. Meanwhile, these values were 98.85%, 98.96% and 97.36% in F_2 generations, for the above three traits, sequently (Table, 7). High heritability estimates in broad sense (Hb) obtained in F_1 and F_2, indicated that most of the phenotypic variability in leaf rust resistance components, was mainly due to the genetic effects. On the other hand, moderately high to high heritability estimates in narrow sense (Hn) were obtained. However, these estimates ranged from 62.02% to 74.52% and from 69.31% to 82.77% in F_1 and F_2 generations, respectively (Table, 7). These results indicated that, leaf rust resistance genes with both additive and dominance effects were found be the major contributing factors in the performance and expression of this type of resistance. Based on these results, selecting resistant genotypes may be useful in the early generations, but it would be more effective if postponed to later ones. High heritability estimates for adult-plant resistance to leaf rust in wheat, has also been documented by Shehab El-Din *et al.* (1996), Ageez and Boulot (1999) and Navabi *et al.* (2005).

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وراثة صفة المقاومة لمرض صدأ الأوراق فى طور النباتات البالغة فى خمسة أصناف قمح خبز مصرية

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أجرى هذا البحث بهدف دراسة السلوك الوراثى لصفة المقاومة لمرض صدأ الأوراق فى القمح والمتسبب عن الفطر (*Puccinia triticina*) ، حيث تم إجراء هذه الدراسة تحت ظروف الحقل بمحطة البحوث الزراعية بالنوبارية ، خلال ثلاثة مواسم زراعية متتالية وهى: ٢٠٠٢/٢٠٠٣م ، ٢٠٠٤/٢٠٠٥م و٢٠٠٥/٢٠٠٦م. وقد أستخدمت فى تلك الدراسة خمسة أصناف من الأقماح المصرية تختلف فى درجة حساسيتها للإصابة بالمرض وهى: سخا ٩٤ ، وجميزة ٩ وجيزة ١٦٨ "مقاومة للمرض" وجميزة ٧ "متوسط المقاومة" ثم جيزة ١٣٩ "صنف عالى القابلية للإصابة بالمرض".

أجريت التهجينات الممكنة بين هذه الأصناف للحصول على نباتات الجيل الأول والجيل الثانى. وذلك لتقويم المقاومة لكل من الآباء ونباتات تلك الأجيال فى طور البلوغ للمرض ، تحت ظروف الحقل بمحطة بحوث النوبارية خلال الموسم الزراعى ٢٠٠٥/٢٠٠٦ وذلك باستخدام وتقدير ثلاث مكونات للمقاومة وهى:

١-النسبة المئوية النهائية للإصابة بالمرض (FRS (%.

٢-المساحة الواقعة تحت منحنى الإصابة المرضى (AUDPC).

٣-معدل تزايد المرض (r-value).

واستخدمت طريقتين للتحليل الإحصائى الوراثى الكمى للبيانات المتحصل عليها وهما:

Griffing (1956) & Hayman (1954)

وقد أوضحت نتائج هذا البحث ما يلى:

- المعنوية العالية للتباين الراجع إلى كل من القدرة العامة على التآلف (GCA) ، وكذلك القدرة الخاصة على التآلف (SCA) لمكونات مقاومة المرض الثلاثة تحت الدراسة – مما يوضح أهمية كل من الفعل المضيف وغير المضيف للجينات المسئولة عن المقاومة فى توارث صفة المقاومة لمرض صدأ أوراق القمح.
- إن طبيعة السيادة للجينات المسئولة عن مقاومة المرض كانت سيادة جزئية "Partial resistance" ، حيث اتضح ذلك من كون النسبة $(H_1/D)^{½}$ والتى تمثل متوسط درجة السيادة – دائماً أقل من الواحد الصحيح لكل مكونات المقاومة تحت الدراسة . وقد إتضح أيضاً أن الآباء المستخدمة فى تلك الدراسة تحمل أليلات سائدة أكثر من الأليلات المتنحية ، ويؤكد ذلك القيم الموجبة لـ "F" .
- وجود زوجين من جينات المقاومة ، والتى تتحكم فى وراثة كل من صفتى المساحة الواقعة تحت منحنى الإصابة المرضى "AUDPC" ومعدل تزايد المرض (r-value) ، بينما يزيد عدد العوامل الوراثية المسئولة عن المقاومة للمرض إلى ثلاثة عوامل تتحكم فى توارث صفة النسبة المئوية النهائية لشدة المرض (FRS%).
- ومن ناحية أخرى فقد أوضحت نفس النتائج أن قيم معامل التوريث "heritability" بمعناها الواسع وكذلك بالمعنى الضيق ، كانت عالية لكل مكونات المقاومة تحت الدراسة مما يدل على أهمية عامل السيادة وكذلك التأثير المضيف فى توريث صفة المقاومة من الآباء إلى الأجيال التالية ، ويوضح إلى حد ما إمكانية إجراء عملية الإنتخاب للنباتات المقاومة لهذا المرض فى الأجيال المبكرة . بيد أن تأخير عملية الإنتخاب هذه إلى الأجيال الإنعزالية المتأخرة – إلى حد ما – قد تكون أكثر فعالية فى ذلك .